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Proceedings— Symposium and Workshop on Wilderness Fire

Missoula, Montana, November 15-18, 1983

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Proceedings of a Symposium Sponsored by:

Intermountain Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture
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National Wildfire Coordinating Group
Society of American Foresters
University of Montana

The Wilderness Fire Symposium held November 15-18, 1983, in Missoula, Mont., can be described in one word: *exciting*! Since its very inception, people have been excited. As I write these words almost a year later, people are still excited about wilderness fire management.

Credit for the initial concept of having such a symposium belongs to William C. Fischer, Research Forester at the Intermountain Fire Sciences Laboratory in Missoula. Bill spent many long hours developing and writing the recently published "Wilderness Fire Management Planning Guide."[1] One day as we were discussing the concept of using fire in wilderness, Bill suggested that we should pause to assess wilderness fire management inasmuch as we had been practicing it for 10 years or more. I said, "Let's do it!" And so we did.

I then formed a program committee chaired by Dr. Bruce Kilgore and consisting of Robert Mutch (both Bruce and Bob were pioneers in wilderness fire), Bill Fischer, and me. This early planning took place in January 1982. Bruce became a prime mover from that moment on. None of us at that time realized either the work involved or the size of the program that would evolve. We were excited, however, and that excitement spread to the estimated 700 people in attendance. More than 600 people registered; their names and addresses are listed at the end of the proceedings.

The symposium was one of a series planned to terminate the highly productive Fire Effects and Use Research and Development Program, conducted by Forest Service Research at the Intermountain Station's Intermountain Fire Sciences Laboratory located Northwest of Missoula, Mont.

Our goal was to openly discuss how well we have managed wilderness fire and current concerns. We wanted to discuss these issues in an open forum, with attendees contributing. During my opening remarks at the symposium, I pointed out that either topic--wilderness or fire--was apt to be controversial; and when we combine them, we are doubly assured of having plenty of controversy. That we did! The arguments are continuing to this day. Our goal was to get them out into the open and to deal with them professionally. I suspect that as the issues of allocation and classification of wilderness are resolved, we will hear more debate about management of wilderness. What we have heard so far is probably just the tip of the iceberg.

One management controversy that has already arisen is whether to use deliberate, scheduled ignitions in wilderness. William A. Worf, retired Recreation Director of the U.S. Forest Service, Northern Region, pointed out that we did not present the cons of using scheduled ignition in wilderness. I therefore invited him to present his views in a paper to be included in the proceedings. In addition, I decided to include the views of Robert C. Lucas and Bruce M. Kilgore, who reviewed Worf's paper. I suppose the process could have continued *ad infinitum*. These papers point out the complexities of wilderness fire management. I suspect that such controversy extends to many other wilderness issues.

Processing papers for this proceedings revealed a frustrating inconsistency in the terminology used to describe wilderness fires. We felt that uniform terminology would facilitate communication among the various Federal resource agencies, State and Province organizations, universities, conservation groups, industry, consultants, and research organizations. I therefore asked Bill Fischer to include his well-thought-out lexicon ("Wilderness Fire Terminology") in this proceedings, and we tried to use it throughout the proceedings even though we did not intend to press for universal adoption. Our hopes were dashed because each agency had its own terminology and good reasons for adherence to its usage. We ended up deferring to definitions used within an agency.

To facilitate communication in this proceedings and to eliminate reader confusion, we shall list some of the most common terms coined by the Forest Service, National Park Service, and Bill Fischer.

We caution readers to heed the official terminology of their respective agencies, and we urge the agencies to strive for literal and consistent meanings. Perhaps over the next decade a clearly understood and uniform terminology will evolve.

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[1]Fischer, William C. Wilderness fire management planning guide. Gen. Tech. Rep. INT 171. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1984. 56 p.

Types of fire	Forest Service term	Park Service term	Fischer's term
Fires ignited by lightning or other natural forces (volcanoes) that are permitted to burn under prescribed conditions.	Fires with unplanned ignition	Prescribed natural fires	Fires with unscheduled ignition
Fires ignited by trained professionals under prescribed conditions.	Fires with planned ignition	Prescribed burns	Scheduled ignition
Unwanted fires started either by natural forces or people (arson or carelessness).	Wildfires	Wildfires	Wildfires

I thank Dr. Bruce Kilgore and the members of the program committee: Gerry T. Baertsch, our general manager; the many speakers and authors; and the many attendees and their supporting agencies. Bruce's energy and attention to detail were particularly important to the successful completion of the symposium and publication of the proceedings. This symposium will serve as a milestone in his future research in wilderness fire management. Bill Fischer deserves further acknowledgment for his outstanding poster session. It added immeasurably to the value of the meeting. I personally thank Gail Hallesy and Patricia Proebstel who did far more than type papers. Their assistance was invaluable.

For their sponsorship and generous support of the symposium, I thank administrators in the Washington Office of Forest Service Research and in the Intermountain Station; and also the Center For Continuing Education, University of Montana; the National Park Service; the Prescribed Fire and Fire Effects Working Team, National Wildfire Coordinating Group; and the Ecology and Fire Management Working Groups, Society of American Foresters.

With these comments I submit these proceedings to the wilderness fire management community. *It has been fun! . . . and exciting!*

JAMES E. LOTAN
Research Forester

CONTENTS

Section 1. Overview of Wilderness and Fire Management

WELCOMING REMARKS--WILDERNESS FIRE

Laurence E. Lassen

I am pleased to see so many different management agencies and universities represented at this symposium. Close working relationships between research groups and management agencies are important in transferring technology from the study and discovery stage to application in the field. We at the Intermountain Station have had a particularly close working relationship with a number of agencies involved in the management of wilderness: the major Federal agencies are the National Forest System, the National Park Service, and the Bureau of Land Management. We have also enjoyed fruitful, cooperative research endeavors with may university representatives. Such teamwork has contributed much to the knowledge and management of this important resource.

Many of you have long been involved in the study and management of wilderness and fire. I believe the issues discussed in this Symposium are important and that the latest information and thinking can greatly contribute to better land management. This Symposium is a highlight of the Intermountain Forest and Range Experiment Station's long history of wilderness fire-related research, some of which dates back to the 1960's. Some of the early work started in the Selway-Bitterroot Wilderness with cooperation between scientists at the Northern Forest Fire Laboratory and the Bitterroot National Forest. This Symposium is one of three being carried out by the Station as part of the Fire Effects and Use Research and Development Program lead by Dr. Jim Lotan. Jim and his people have been enthusiastic about the meeting since its inception. This symposium is a timely effort to examine our track record and question how we are doing.

Some of the early work in wilderness fire dates back to about the time the Fire Lab was constructed in Missoula. During the 1960's, Mike Hardy's fire management project at the Fire Lab was assigned a problem area in wilderness fire control. Lack of funding, however, precluded much progress in this area.

In January 1967, Art Brackenbush, then Chief of the Northern Forest Fire Lab, presented a paper at a wilderness meeting in Great Falls, Mont., entitled "Fire in the wilderness." In that paper, Art outlined a research approach he felt was necessary to provide managers the information needed to practice what we now refer to as fire management in parks and wildernesses.

Several years later, in 1970, Project Leader Hal Anderson assigned Bob Mutch, then an Intermountain Station scientist, to design and conduct a research study that ultimately resulted in the 1972 Whitecap Creek Fire Management Plan in the Selway-Bitterroot Wilderness. This was the first plan to be approved by the Chief of the Forest Service. It was a truly cooperative research-management effort. Regional Fire Chief Bud Moore, Forest Supervisor Orville Daniels, District Forest Ranger Dean Byrne, and Wilderness Fire Planner Dave Aldrich, all have played key roles on the National Forest management side.

In 1974, the Intermountain Station joined with the Intermountain Fire Council and Tall Timbers Research Station in presenting a major symposium on fire and land management that highlighted park and wilderness fire management.

Currently, Project Leader Bruce Kilgore, under the direction of Program Manager Jim Lotan, is involved in fire history and fire management studies in Glacier National Park in Montana and the River of No Return Wilderness in Idaho. The Glacier National Park studies are in cooperation with Dr. Ron Wakimoto of the University of Montana, Missoula.

This meeting gathers together an impressive array of knowledgeable speakers. Many of these speakers are pioneers in park and wilderness fire management, many are actively engaged in fire management or research activities, and all are experts on the topics they present. The major emphasis is on programs, policies, and issues of fire management for those areas managed as naturally functioning ecosystems. It is timely to examine how well things are going and what still needs to be done or changed to better manage these important reserves.

Paper presented at the Wilderness Fire Symposium, Missoula, Mont., November 15-18, 1983.

Laurence E. Lassen is the Director, Forest Service, U.S. Department of Agriculture, Intermountain Forest and Range Experiment Station, Ogden, Utah.

In the spirit of sharing experiences from several land management agencies, Symposium speakers will:

1. Explore basic wilderness management philosophies.

2. Explain current wilderness and fire management policies.

3. Identify current fire management programs.

4. Identify and discuss various fire management issues.

5. Present various fire management planning considerations.

6. Discuss operational techniques for park and wilderness fire management.

The purpose of this Symposium is to develop state-of-knowledge information on the science and management of wilderness and fire. This purpose is certainly in keeping with a major goal in recent years at the Intermountain Station: to summarize, synthesize, and deliver to managers information about key subjects in the Intermountain and Rocky Mountain West areas. We have been able to make technology transfer efforts such as this only because we have conducted a great deal of research over several decades. We have accumulated this reservoir of knowledge from the research experience of managers in the field. It is appropriate now to tap this reservoir and ensure that the knowledge is transferred to other managers.

We of the Intermountain Station are pleased to share sponsorship of this important Symposium with the Center for Continuing Education of the University of Montana; the National Park Service; the Prescribed Fire and Fire Effects Working Team of the National Wildfire Coordination Group; and the Fire Ecology and Forest Ecology Working Groups of the Society of American Foresters. We look forward to a productive 4 days.

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SOCIOPOLITICAL ENVIRONMENT FOR FIRE AND WILDERNESS MANAGEMENT IN NATIONAL PARKS

Russell E. Dickenson

INTRODUCTION

The management of fire, whether wildfire or prescribed fire, is the most overt form of resource management practiced in parks and wildernesses today. Fire management is highly manipulative; yet it is simultaneously geared to replicate the effects of natural ecological processes. This Symposium, with its intensive coverage of the topic, is an excellent arena for discussing the academic and the applied aspects of using fire in wilderness.

To set the stage for discussions of fire as it pertains to the National Park System, it is useful to characterize the nature of the National Park System and its interaction with the National Wilderness Preservation Act.

There is a tendency to oversimplify the National Park System and to envision it as an aggregation of Yellowstones and Yosemites. Although those great parks are among its gems, the National Park System encompasses a wide array of other areas throughout the United States. I shall use the term "parks" throughout this presentation for any of the units of the National Park System. And, for purposes of this discussion, legally defined wilderness is subject to the same management practices as any other natural zone found in parks.

The fire management program of the Service attempts to blend the fire management needs of the diverse park areas into a comprehensive systemwide program. Parks are a focal point of public attention. Their broad public recognition attracts people. As more people come to parks, there is increasing use of fire-prone park lands and, indeed, a greater occurrence of wildfires in natural areas. This requires a response from us: We must better educate our visitors about the hazards they may create and the value of prescribed fire in a managed program.

The National Park System areas may be grouped in a few broad categories for purposes of this discussion. We have the broad range of natural parks in the System, as large and diverse as the Yellowstones and Yosemites; and there are much smaller parks, sometimes focusing on specific species, as at Saguaro National Monument. Some parks, such as Glacier on the Canadian border and Everglades in south Florida, have complex fire histories. The public usually thinks of these natural parks when there is a mention of wilderness and fire.

Golden Gate National Recreation Area in California and Gateway National Recreation Area in and around New York Harbor are two classic examples of another type--urban parks. These parks also have complex fuel systems periodically subject to wildfire and have niches in which vestiges of wilderness may still be found. Bandelier National Monument in New Mexico, set aside primarily to represent the culture of the southwest Indians, represents yet another park type. Although its primary theme is cultural, much of Bandelier can also be characterized as wilderness. A significant share of the recreational use in the National Park System occurs in recreational areas with limited wilderness, such as the Santa Monica Mountains in California or Canaveral National Seashore in Florida.

The emphasis on each park's resources and its wilderness values is important, but size and location also obviously influence management. In sharp contrast to National Forest System areas, the National Park System units may vary from only a few acres to millions of acres. They are distributed in virtually all climatic regions of the United States, all the way from War in the Pacific National Memorial on Guam, eastward to Acadia National Park on Maine's coast, and from the tropical Virgin Islands National Park to the Gates of the Arctic National Park, which is north of the Arctic Circle. Their immense variety contributes to an incredible variability in park fire and wilderness management needs.

CONGRESS

Park Service Organic Act

The environment in which the National Park Service fire management program has evolved is intertwined with the congressional mandates for the National Park System. Public involvement with elected representatives, in Congress and the Executive Branch, has molded the modern National Park System. This is particularly pertinent to the 1916 National Park Service Organic Act, which established the bureau. We continually reflect on the basic premises expressed in that Act, the essence of which permeates the management objectives of each park and guides its fire management program.

Paper presented at the Wilderness Fire Symposium, Missoula, Mont., November 15-18, 1983.

Russell E. Dickenson is Director, National Park Service, U.S. Department of the Interior, Washington, D.C.

The law's basic premise, protect cultural and natural park resources, is sometimes portrayed as an insoluble dilemma. It is, however, a charter to balance priorities between two broad objectives. Aspects of the Organic Act are particularly germane to fire management and strongly parallel the Wilderness Act that followed nearly 50 years later.

In this Act, the Service is charged to "conserve the scenery and natural historic objects and the wildlife therein." The wisdom of conserving these objects (not necessarily preserving them in a fixed state, but providing for the dynamic variation of the natural systems) is significant. In addition, the Act goes on "to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations." As you can readily appreciate, these simple words can be interpreted in numerous ways in relation to fire and the management of the national parks in a public setting.

The profound implications of the Organic Act have affected all subsequent activities of the National Park Service. As new parks were added, creating the system of more than 330 units that we know today, each park was still guided by the words of the Organic Act. The basic premise of the National Park Service Organic Act are implicit in the intent of the later legislation, the Wilderness Act in 1964, which restates the need to provide for public use and enjoyment, as well as to protect and preserve resource values. Wilderness designation has been imposed upon those undeveloped areas that meet <u>both</u> the criteria of the Wilderness Act and the criteria for park status.

Wilderness Act

The authorizations and authorities included in the Wilderness Act characterize the theme of this presentation. The process of reviewing the yet undeveloped portions of the National Park System and delineating those areas within a park that would lend themselves to wilderness designation triggered intense public involvement with park management staff at all levels. Converting the desirable, yet theoretical, goals of the Wilderness Act to the real world of metes and bounds on ground in a park has generated strong emotions. Reviewing undeveloped lands according to this new set of criteria sometimes conflicted with the original objectives of those who had supported establishing these parks. In some cases, developments or the prospect of developments had been an issue in drawing some park boundaries. In addition, many parks had private lands within their boundaries and other nonconforming uses that had to be accommodated as we developed fire management plans.

The Wilderness Act came into being near the culmination of the Mission 66 program in the National Park System. This was a period of increased visitor service developments and accessibility for the National Park System. Public involvement in the Wilderness Act and subsequent area designation hearings provided an opportunity for a retrospective look at areas in the National Park System that had been developed and areas that remained undeveloped. Increased interest in wilderness and the creation of a long-needed development program for basic interpretive and management facilities spurred new interest in the undeveloped portions of the parks. One result of this interest has been a renewed effort to resolve sometimes competing uses and objectives.

The National Park System presently encompasses nearly 80 million acres (32.4 million ha), of which almost half has been designated as wilderness by Congress. An additional 10.5 million acres (4.5 million ha) is under consideration, and studies are still underway in another 31 parks. The numbers are deceptive, however, as most of the designated wilderness is in Alaska, but the study program focuses on the entire nation.

It is important to reiterate here that although the wilderness designation has great meaning in terms of visitor uses and activities, it is not a significant factor in our fire management program. Fire management focuses on the vegetation and its needs rather than on artificial designations. Other Federal land managers face a different problem because the wilderness designation may restrict certain multiple-use objectives, thereby fundamentally affecting objectives of the fire management program as well.

The efficient achievement of Agency missions is essential. We have an obligation to attain our management objectives for these unique lands with the financial and personnel resources available. Fire, by its very nature, requires advance preparation; yet it often triggers a reactive response. We must ensure that personnel with knowledge, skills, and the needed technological resources are available for sound fire management in parks and wilderness.

No discussion of the sociopolitical environment for fire management in the National Park System would be complete without addressing the Alaska National Interest Lands Conservation Act (ANILCA). This one law more than doubled the size of the National Park System and incorporated the least-visited and least-developed acreages found in the System. Obviously, much of the acreage within Alaska is snow, rock, ice, and water, but the designated areas also incorporate many millions of acres of vegetated park land. Six major parks are within portions of Alaska that are subject to frequent wildland fires. In them, natural sources of ignition are a major component of our fire management program.

Another unusual aspect of fire management resulted from ANILCA. Within the Department of the Interior, the Bureau of Land Management (BLM) had operated an extensive fire protection system for the public lands they administered in Alaska. The new national parks were withdrawn from those public lands and assigned to the National Park Service for management. The same law withdraws other lands as refuges to be managed by the Fish and Wildlife Service. All Interior bureaus represented in Alaska had traditionally cooperated in BLM's fire management program because BLM was the dominant land manager; however, ANILCA radically altered the land management responsibilities of the various bureaus. Nevertheless, we chose to have BLM continue as fire management coordinator. Individual area fire management plans have been modified to conform to the objectives defined by Congress in ANILCA, but the suppression program's operation continues to be principally BLM's responsibility. Rather than scrap a functional association, we have succeeded in revamping it to serve revised objectives.

Clean Air Act

The Clean Air Act and its amendments were born of an era in which the public, for the first time, became aware of global ecological dynamics. The public debate on clean air revealed that some materials carried by the air do cause an imminent threat to the public; thus a global issue was brought to a level of personal concern.

For parks, clean air is closely tied to public interest. The majority of visitors to parks are there for short periods only. Furthermore, they visit during vacations or for a day's recreation. Under such circumstances, they have an understandable desire for conditions approaching perfection. They do not want rain, snow, fog, smoke, or anything else that will impair the quality of their visit.

Although we cannot control natural forces, we are expected to control the effects of our own actions. In respect to fire management, the critical issue to the visitor is usually smoke. We must work to minimize the impact of smoke from prescribed fires upon them. Beyond that, we must be able to explain the reasons for those intrusions that are a by-product of essential fires.

For this reason, our fire management plans explicitly define the use of prescribed fire. Visible flames and scorched earth or vegetation are explained through our interpretive program. A misunderstanding of use of prescribed fire is trouble for visitor and management alike. Fortunately, through good interpretation almost all visitors strongly support our fire program in spite of smoke and burned vegetation.

The natural interaction of smoke from wildland fuels with ecosystems throughout the United States has been acknowledged and studied over the years. The adverse impact of industrial pollutants is also well known. In the absence of social and political considerations, however, a natural lightning-caused fire burning in the woods would go unnoticed. In reality, we must reconcile these natural processes found in wilderness with Clean Air Act provisions that prohibit degradation of air quality in many park areas.

With or without our help, the large number of people who visit and enjoy national parks will interpret the meaning of any smoke they find there. If they perceive smoke as an element of the natural fire process in wildlands, then they may react to it objectively or even participate in monitoring its action and behavior.

Smoke in the parks has sociological and psychological implications as well. This aspect is exemplified by an experience that Lon Garrison, former superintendent of Yellowstone National Park, had on a visit to Yosemite Valley. Lon had worked throughout the Park System and was instrumental in the early fire program in Yellowstone National Park. While staying in Yosemite Lodge, Lon awoke to the smell of smoke. His first reaction was concern that the lodge was on fire. Lon, however, analyzed the situation: There were no sirens; there was no visible source of smoke in or around his room; he recognized the smell as smoke drifting into the valley from wildland fires. A less informed visitor easily could become terrified by such an experience. Our staffs must not only manage the fires but also the entire areas impacted by smoke; they must take special care to keep visitors and neighbors aware of events in progress.

One of our fires, the Ouzel Fire in Rocky Mountain National Park, produced large volumes of smoke that drifted from the park to where different air quality rules apply. In an adjacent community, a nonattainment area under the Clean Air Act, smoke must be judged by different criteria. Because it was a prescribed fire, the National Park Service was cited for violation of the Clean Air Act by the County Air Pollution Board.

The National Park Service will remain sensitive to the implications of the Clean Air Act, as well as the effects of smoke on visitors and the tourism industry. We still need to perpetuate, so far as possible, natural systems. At the same time, we are realistic and acknowledge our obligations to the law and to the public. We must guide each fire management progam so as to achieve the needs of the park with minimum adverse impact to the public.

PUBLICS

Visitors

Visitors are a crucial element of park programs. Their role can be likened to that of sports fans. The presence of fans assures the financial and political stability of the team. Without them, franchises fold and stadiums are used for other purposes. So it is with parks: without the fans, we too can lose our franchise. Thus, we have an obligation to protect and preserve the resources for which the parks were created. If we fail to field a competitive team or use a workable game plan, we will lose the support of visitors and potentially threaten the existence of our parks.

It is easy to point to rising park visitation figures, just as sports leagues point to rising attendance. But our history is marked by the loss of little-known or appreciated parks, losses that parallel the demise of major league baseball in Washington, basketball in Minneapolis, and hockey in Denver. Indeed, like baseball in Milwaukee, we've even seen revivals--an abolished Santa Rosa Island National Monument is now a key element of Gulf Islands National Seashore.

We must cultivate the continuing support of our friends and neighbors or face extinction of parks we seek to keep in operation. Our fire management programs must consider such matters. Just as fire cannot survive in a vacumm, a fire management program cannot survive in a political vacumm.

The interpretive effort of the National Park Service is essential to the success of the fire management program. Through written materials provided in advance of the visit and through on-site interpretation and interaction with visitors, we can create the understanding that is crucial to success. When the public is aware of the National Park Service fire management programs and comprehends why these programs are vital to natural systems, we find that the majority of the public is supportive.

Neighbors

Unlike the national forests and the wilderness areas within them, many units of the National park System are relatively new. Many park areas reflect efforts by local groups to commemorate or set aside unique features. Because these groups have a direct interest in these areas, it is only natural that they also would actively participate in dialogs on the associated fire management program.

In contrast, our larger natural areas often share boundaries with adjacent land management agencies rather than with private individuals, and in many of the new areas we find complex land patterns that complicate management of the natural systems. Even in the extensive lands of Alaska, private inholdings will present continuing concern in management of the parks. This preempts some of our latitude for management of fire and its associated smoke.

Adjacent Land Management Agencies

We have been fortunate to join with the U.S. Forest Service in establishing fire management zones that encompass portions of parks and adjacent forest wilderness. This cooperation resolves sociopolitical difficulties and achieves natural systems management goals.

In other areas where management practices involve such activities as fuel reduction outside the park and in-park prescribed burns to restore natural fuel loading, we find a grayer area. It can be difficult for the public to understand the idiosyncrasies of the management styles caused by different objectives among government bureaus. The management programs of two agencies must be blended locally to facilitate the timing and dispersal of smoke. Such issues can be so complex that generalized discussions are impossible. Local facts and specialized criteria then become the primary concerns.

The timing of public visitation and the need for essential commercial services and facilities can also be restrictive factors. Many parks experience short seasons of commercial activity that must make them economically feasible for an entire year. Superimposed upon that restricting concern is the random occurrence of wildfires. Where prescribed fire, either natural or staff-initiated, is involved, management must make decisions that recognize potential effects on the concessionaire and the visitors.

Organizations

Nationally, the National Park Service deals with many organizations that have particular interests in national parks. Additionally, many other special interest groups also have a vested interest in the Service. These groups carry on an active dialog with park managers, they generally have supported our evolution from simple fire suppression to a comprehensive fire management program that has blended various mandates into an acceptable program. These groups do not all have the same interests, however, nor do they all agree on a particular program. Conservation groups, hikers' associations, recreation vehicle clubs, and many other organizations may have very different perceptions of any particular managed fire.

The National Park Service also plays multiple roles with State and local governments. Our superintendents work with their State and local officials as Federal land managers at the same time they are perceived as "managers of tourism," whose parks will attract visitors and their money. And park employees contribute to the community tax base and draw on community resources.

National Park Service

Any discussion of wilderness and fire in the National Park System would be incomplete without acknowledging the park staffs that make its programs possible. Fire management and natural resource management programs must be coordinated to accomplish the objectives for which the areas were set aside. Our most direct contact with the public is by uniformed park rangers, interpreters, and resource management staffs. Uniformed personnel, in "Smokey Bear" hats, are well known to the public, and these individuals directly project the image of our management program. On a local scale, furthermore, the direct participation of park maintenance and administrative personnel in the local communities significantly influences how various management programs of the Service are received.

Every employee, then, becomes a messenger for our programs. If we fail to communicate our message to our own employees, we fail to gain the first level of support that we need. Their support--through education--will be reflected in how they carry our message to the communities of visitors and neighbors whose support is essential to our success.

CONCLUSION

The process of managing fire and natural resource areas in the national parks is both sociological and political. Park staffs hosted 245 million visitors in 1982 and coordinated activities with numerous organizations and interest groups. We must consider that "political" process desirable. It epitomizes government in a free society. Our challenge is to be able to blend the technical knowledge and expertise associated with fire management today into the social and political realities of park and wilderness management.

The careful evolution of fire management policy within the National Park System guides many other programs and provides a point of reference. Management and staff commitment will assure application of a technical program formulated to suit an individual park's needs.

We must remember that fire management objectives cannot be achieved in isolation. Both our agencies and our publics need to support and understand the role of fire for sound management of these complex natural systems that we call parks and wilderness.

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MANAGING WILDERNESS TODAY FOR THE FUTURE

Raymond M. Housley

ABSTRACT: Wilderness management is a difficult task. Each wilderness is a finite geographical area with its own specific characteristics and unique ecosystems. Each area must be managed in a way that ensures that the solitude and untrammeled conditions envisioned in the Wilderness Act are perpetuated. Our well-intentioned fire suppression policies of the past may have interfered with natural ecological processes. A policy change permitting the use of prescribed fire from planned ignitions[1] within wilderness would be justified only if these ignitions tend to offset the results of fire suppression for the past 80 years.

INTRODUCTION

There is clearly a need in wilderness management for a stronger and more consistent national policy. Such policies must take into account the provisions of law, public concerns, and solid scientific information.

How much wilderness the nation needs or which areas should be included in the system are clearly questions to be decided by Congress--although U.S. Department of Agriculture, Forest Service provides recommendations, factual data, and professional perspectives through the Secretary of Agriculture and the Office of Management and Budget as part of the basis for making these decisions. Sometimes these officials think we have been too conservative in our recommendations. Sometimes they think we have been too liberal. And there may have been cases in which the decision indicates we were just right. I cannot think of an example of the latter, however.

Many interest groups work to influence these decisions in the Administration and in Congress--generally by seeking to limit or to expand wilderness designation or to permit or exclude certain activities. Their input helps shape wilderness management policies. The provisions for mining and mineral leasing in the 1964 Wilderness Act and for livestock grazing in the Colorado Wilderness Bill of 1980 are good examples of this. State and local governments also influence policy development by recommending areas for wilderness designation and by pointing out local views of impacts and benefits. Certainly a State's congressional delegation has the key role in the process.

Paper presented at the Wilderness Fire Symposium, Missoula, Mont., November 15-18, 1983.

Raymond M. Housley is Deputy Chief, National Forest System, USDA Forest Service, Washington, D.C.

Once a wilderness bill has passed, however, it becomes the appropriate resource agency's responsibility to manage the designated Wilderness and to care for it. Policy for wilderness management is developed by professional land managers with advice from specific wilderness user groups.

A GUIDING PHILOSOPHY FOR WILDERNESS MANAGEMENT

Following enactment of the Wilderness Act of 1964, Forest Service management practices were shaped to reflect the Act's philosophies. Although most of our management practices already fit the Act's requirements, others had to be modified or gradually redirected. At that time, Richard Costley--then Director of Recreation for the Forest Service--wrote in American Forests that "Wilderness managers are going to be confronted with problems in wilderness management a long time after the job in wilderness classification is completed."

He was prophetic--and he characteristically understated the situation! Translating the Wilderness Act's language into administrative policies and on-the-ground actions has often spawned controversy. Though Congress has helped to solve some management problems legislatively, it has also added some new dimensions to the wilderness management challenge.

Today we still face problems with how best to manage the Wilderness System. Managing wilderness is difficult work because each Wilderness is a finite geographical area with its own specific characteristics and unique ecosystems. Each area must be managed within the constraints of the ecosystem and of the specific wilderness legislation that created it to ensure that the solitude and untrammeled conditions envisioned in the Wilderness Act are perpetuated.

The need for consistency between the objectives of wilderness designation and the objectives of wilderness management has not always been recognized. For the first few years after the Wilderness Act's enactment, wilderness enthusiasts generally praised the Forest Service's "pure" management philosophy--at least until they realized that the agency wanted to apply the same strict standards in identifying areas to be added to the Wilderness System as it used in managing them. They countered the two-step approach: "flexible" criteria for admitting areas into the system, followed by stronger, stricter standards for managing them once they were in.

[1]Editors' note: Please refer to the Foreword for comments on prescribed fire terminology.

Needless to say, both the Forest Service and the environmentalists maintained they were correctly interpreting the intent of the Wilderness Act--and perhaps both were correct. Others, who conduct other activities in wilderness--such as weather modification and precipitation telemetering--are equally sure they are right. Wildlife enthusiasts are sincere in their belief that the Wilderness Act intended habitats to be improved, especially for endangered species or "wilderness-related" ones. But the essentially pure philosophy the Forest Service follows--the strict constructionist one--allows little room for these interpretations.

The existence of so many interpretations demonstrates why it is becoming increasingly difficult to manage wilderness. There are even more reasons. During the past 10 years, Congress has established several new wilderness areas with uses that do not conform to the Wilderness Act's original intent. Though we will manage those areas accordingly, we are concerned that pressure will build to make these permitted exceptions the norm for all wilderness areas. Part of the rationale for such an approach is the contention that because Congress did not prohibit such uses in recently designated areas, it must be the sense of Congress that these activities should be permitted in all wilderness areas. If there is very much erosion of the legislation's original purpose, the overall quality of the system could be threatened.

How can we maintain an enduring wilderness resource in the face of so many counteractive pressures? We believe at least part of the answer is found in the strong management philosophy developed by such Forest Service wilderness leaders of earlier generations as Bob Marshall and Aldo Leopold. We think the Wilderness Act itself states the direction and provides the rationale. Nevertheless, maintaining balance may still be our biggest management challenge. We hear the message conveyed by the cumulative actions of Congress, but we believe it is not inconsistent with that message to maintain the benchmark of quality--"purity" if you will--to ensure an enduring resource of wilderness for future generations. We believe the Wilderness Act directs that we do no less. Yet the purity benchmark is not simple to determine nor without entanglements, and fire in wilderness is one of the complicating factors.

FIRE MANAGEMENT IN WILDERNESS

The Forest Service is now considering changing policy to permit prescribed fire (with planned ignitions) in wilderness to accomplish wilderness management objectives. This policy change would be justified only to the extent that prescribed fire offsets the effects of past fire suppression. This policy change is ultimately based on the intent expressed in the Wilderness Act.

Admittedly, the Wilderness Act is lengthy and complex and often seemingly contradictory legislation. It defies easy understanding. Each part must be read in the context of the whole. The objective of the Act is set forth in the first sentence:

> to assure that an increasing population accompanied by expanding settlement and growing mechanization, does not occupy and modify all areas within the United States. . . .

Forest Service wilderness management direction is set out in section 2(a), which declares that Wildernesses:

> shall be administered for the use and enjoyment of the American people in such a manner as will leave them unimpaired for future use and enjoyment as wilderness, and so as to provide the protection of these areas, the preservation of their wilderness character. . . . Wilderness shall be devoted to the public purposes of recreational, scenic, scientific, educational, conservation, and historical use.

Congress defined wilderness in section 2(c) of the Act:

> A wilderness, in contrast with those areas where man and his own works dominate the landscape, is hereby recognized as an area where the earth and its community of life are untrammeled by man, where man himself is a visitor who does not remain. An area of wilderness is further defined to mean in this Act an area of undeveloped Federal land retaining its primeval character and influence, without permanent improvements or human habitation, which is protected and managed so as to preserve its natural conditions and which (1) generally appears to have been affected primarily by the forces of nature, with the imprint of man's work substantially unnoticeable; (2) has outstanding opportunities for solitude or a primitive and unconfined type of recreation; (3) has at least five thousand acres of land or is of sufficient size as to make practicable its preservation and use in an unimpaired condition; and (4) may also contain ecological, geological, or other features of scientific, educational, scenic, or historical value.

The intent of the people who drafted the Wilderness Act was to preserve areas that remain today as they have through time, where natural systems are allowed to operate and where the works of humans have little, if any, impact.

As for the role of fire in wilderness ecosystems, it is becoming clear that our well-intentioned suppression policies in the past may have interfered with natural ecological processes. Fire suppression has often allowed natural succession to progress to a successional stage it never reached when fire was unchecked. This has also allowed fuels to accumulate in many areas to the point where a fire starting under the right conditions could generate a wildfire sufficiently intense to cause an unnatural change in the ecosystem.

The wilderness of the National Forests is diverse. In many cases wildernesses are surrounded by valuable timber stands, expensive developed areas, and high downstream values. Wilderness does not exist in a vacuum; whatever happens or originates within a wilderness area can affect adjacent lands. Therefore, it is Forest Service policy to suppress all wildfires--whether within a wilderness or outside it--by containment or control. The objective here is to select the strategy that results in the least cost and least damage to the resources, including the wilderness resource. The suppression strategy selected depends upon the situation and the fire management direction for that area.

Under present policy, a fire originating from an unplanned but natural ignition--from a lightning strike, usually--can be designated as a prescribed fire if it meets certain criteria for that area.

Since 1972, we have successfully used such unplanned ignitions within some wildernesses; however, because the interval between unplanned ignitions can be long and all fires that occurred before plan approval were quickly suppressed--stand composition changed. Natural fuel loadings also increased in some areas to the point where unplanned ignitions could result in damaging, high-intensity fires. Had we not interfered with the natural process by suppressing fire in the first place, this situation might not have occurred.

But we did interfere. As a result, we have inadvertently helped create a situation that is becoming unmanageable. In these areas, fire cannot resume a natural role without creating some additional unnatural results. Because the outcome would not be acceptable, we have felt we had little choice but to continue to suppress these fires, thus further exacerbating the problem.

This situation has led us to consider using planned ignitions in wilderness on a case-by- case basis but only with the caveat that such prescribed fires would be used only to enable fire to again play a more natural role in wilderness and that private property, other resources, and downstream values outside wilderness would be protected.

In using fire as a wilderness management tool, we need to recognize the infinite variety of situations we face. These fall into six groups, each requiring different handling:

1. Wilderness ecosystems whose development was not influenced by fire. In these areas, even lightning fires have played only a minor role; therefore, there is no need for planned ignitions.

Examples of such ecosystems are the alpine and subalpine ecosystems in the Rocky Mountains, Sierra Nevadas, and the Wallowa Range.

2. Ecosystems in Wildernesses that have been influenced by high-intensity fires at such infrequent intervals that traditional suppression policies have had little impact upon ecosystem structure or function. In these ecosystems, lightning fires occur frequently and can often play their natural role without endangering the entire wilderness resource or adjacent and downstream values. Smoke from these fires usually does not create off-site safety problems or negatively affect smoke-sensitive areas. If adverse impacts are encountered, the unscheduled ignitions(s) can be contained or controlled without damaging the wilderness ecosystem. In such situations it appears there is little no need for scheduled ignitions.

Examples of such ecosystems are the desert ecosystems and the mixed conifer ecosystems in the Rocky Mountains and Blue Mountains.

3. Wilderness ecosystems in which lightning-caused fires have occurred frequently. In such areas, traditional suppression policies have created an unnatural absence of fire as a result uncharacteristic plant communities have developed to the point where adjacent resource values would likely be threatened by lightning-caused fire during the fire season. In other cases, lightning fires occur so infrequently that it will take many years to offset effects caused by years of aggressive fire suppression. In either case, planned ignitions could supplement unplanned ignitions until lightning-caused fires could again be allowed to play their natural role under carefully prescribed conditions.

Examples of such areas are the mixed conifer ecosystems in the Sierra Nevada Wildernesses of the Forest Service's Pacific Southwest Region, the ponderosa pine ecosystems in the West, and the lodgepole pine ecosystems in the Rocky Mountains.

4. Ecosystems in wilderness that are essentially fire-dependent. Excluding fire from such ecosystems has caused uncharacteristic plant communities to develop. Lightning ignitions have the potential to develop into high-intensity wildfires that threaten off-site resources and downstream values. Planned (scheduled) ignitions in such areas conceivably may be required on an interim basis to restore the natural role of fire and to reduce the damage to adjacent off-site values caused by recurrent wildfires.

Examples of such ecosystems are chaparral ecosystems in California, Arizona, and New Mexico Wildernesses.

5. Wilderness established under legislation with specific provisions for using fire to maintain specific ecosystems or values.

Examples are the fuel breaks adjacent to and inside the Santa Lucia Wilderness in the Pacific Southwest Region.

6 Wildernesses that have been added to the National Wilderness Preservation System in the past 8 years pose new challenges. An example is a wilderness where fire cannot play a natural role because burning the vegetation types within it will threaten off-site values under severe wildfire conditions.

An example is the Bradwell Bay Wilderness in the Southern Region.

Obviously, there is an extremely wide range of fire situations in wilderness. Each case must be evaluated on its own merits.

For example, smoke from prescribed fire is a temporary but inevitable environmental consequence. It degrades visibility and negatively affects the wilderness experience for visitors. Visitor use and visibility therefore need to be considered in planning and carrying out prescribed fire in wilderness areas. Smoke management is both art and science. Thanks to advances in research--some of which are being reported at this conference--we have the tools needed to conduct an intelligent smoke management program. We are working on improving these tools and filling data needs. But we need to continually use the best available smoke management practices, or find our use of fire restricted further.

CONCLUSIONS

In summary, fire planning for each area must be based upon the fire ecology of the area. We must also look at the legislative history of each area to determine the specific intent of the Act in establishing each wilderness. Only then will we have a basis for using prescribed fire that is consistent with wilderness management objectives.

Planned ignitions can be a valuable tool whether used inside or outside wilderness. If used inside wilderness, prescribed fire must be used in a manner that conforms with the Wilderness Act and not merely to enhance the outputs of various resources and values.

Any policy of planned ignitions in wilderness should not mean the wholesale use of such prescribed fire in all wilderness areas. We need to proceed slowly and to consider planned ignitions only where they are obviously needed to allow fire to regain its natural role.

245 GUIDING PHILOSOPHY FOR MANAGEMENT OF NATURAL ECOSYSTEMS IN NATIONAL PARKS

Robert D. Barbee

ABSTRACT: The philosophical framework within which the natural ecosystems in the national parks are managed has been evolving for over a century. Levels of management sophistication have changed from those offering strict protection of park resources, through an era of selective protection, to one which is guided by ecological principles.

INTRODUCTION

The National Park System of the U.S. Department of the Interior, National Park Service, offers a special contribution. It has served as a model for countries throughout the world. In addition, it has introduced the notion of preserving natural settings for their intrinsic noncommercial value, a relatively new concept of land use. Although the precise origin of the idea for preserving natural environments is somewhat obscure, the idea did find legislative expression in 1864. In that year, Abraham Lincoln signed legislation into law that ceded Yosemite Valley and the nearby Mariposa Grove of giant sequoias to the State of California to be preserved as a public park.

Yellowstone, the first "national park," was established by an act of Congress in 1872. This Act articulated a new land policy that directed park management to:

> provide for the preservation, from injury or spoilation, of all timber, mineral deposits, natural curiosities, or wonders within said park, and their retention in their natural condition.

Thus began the preservation movement; it pioneered a new concept of land use, which continues today at numerous government and private levels. The results of this movement are perhaps most evident within the National Park System, which preserves the greatest diversity of natural ecosystems on Earth. As inroads and development continue to accelerate and modify the land, the national parks and monuments have become increasingly important as places that perpetuate a baseline of relatively unmodified land and the associated natural processes. This fact alone places tremendous responsibility on those whose job it is to manage these lands in an ecologically sensitive way.

PARKS: CHILDREN OF POLITICS AND THE CONCEPT OF STRICT PROTECTION

Most units within the park system were set aside through the political process. Legislation establishing parks was enacted because individuals or interest groups perceived a threat of exploitation or development to an area already recognized as having unusual value.

It was only logical that strict protection developed as a management philosophy for the early parks: protection of timber from axe and saw, wildlife from hunters, minerals from miners, and rangeland from grazing livestock. The new parks such as Yellowstone, Mount Rainier, Sequoia, and Yosemite were administered by the United States Army. This served to reinforce the management philosophy of strict protection.

After 1916, the newly established National Park Service began to manage the park system. By 1916 there were 27 natural area parks within the system. The best management of park resources was considered no management. "Let nature take its course" became the hallmark of the National Park Service. The natural areas within the system were, and still are, billed as great living museums of natural history and scenic beauty, with only incidental human influences and modifications. Keeping these natural wonders essentially unimpaired seemed like a reasonable aspiration and to a large degree it has been achieved; nevertheless, a well-conceived, ecologically based management philosophy was not initially present.

GOOD RESOURCES VERSUS BAD RESOURCES AND THE CONCEPT OF SELECTIVE PROTECTION

In fact, nature was not allowed to take its natural course in these areas; instead nature received human assistance. What was practiced was a form of selective protection. Along with their successful efforts to protect the parks from human exploitation, managers also "protected" the parks from certain natural depredations and forces. Some resources were perceived as "good" and others as

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"bad." The good resources were protected from the bad resources. Ungulates were viewed as good and predators as bad; trees were all good, but anything that destroyed them was bad; therefore, fire was bad. Fish were good, and most things that ate them (besides people) were bad. In the words of Lyle H. McDowell, a National Park Service official responsible for consolidating the Service's resource management posture in the 1960's,

> Protection as a management concept was steeped in emotionalism and sentiment and coated with the best of intentions but unfortunately it is misdirected.

One must hasten to add, however, that the managers of the early 20th century performed according to the state-of-the-art and were pursuing a course of action considered rational and enlightened.

PROTECTION OF THINGS BUT NOT PROCESSES

Viewing these practices from the secure vantage point of hindsight, it can be seen that the "naturalness" of the parks was not guided by ecologically sound policies. If nature had been allowed to take its course and if all processes had been protected, many of our wildland parks would be in better condition today. The park environment was regarded as an object to be preserved, and therefore the need to preserve natural processes, including fire, was ignored.

Some park forest management illustrates this fallacy. Forests were protected, but what about the natural processes associated with them? Native forest insects were sprayed to protect the forests, but spraying inhibited the natural forest rhythm. In most western forests, natural wildfires were as much a part of the evolutionary vegetative development as sunshine and rain, but for years these forests were "protected" from natural wildfire. The biological response induced by withdrawing this natural process has often been significant and undesirable.

ENTER THE ECOLOGISTS

By the mid-20th century, ecologists had assembled a basic understanding of many aspects of the "land organism." With the growing sophistication of this budding science, wildland park managers could no longer remain in intellectual isolation from ecological realities. By the early 1960's it had become obvious that an incisive management policy was essential if national parks were to remain the bastions of naturalness that Congress intended.

In 1963, the Secretary of the Interior established a committee of eminent scientists chaired by the late Professor Starker Leopold, ecologist at the University of California, Berkeley, and challenged them to submit recommendations for an ecologically sound park management policy. Although their primary focus was on wildlife management, the committee found that no aspect of park resource management could be considered in isolation. For example, they probed the dilemma brought about by selective protection and turned their attention specifically to those forests located within the parks of California's Sierra Nevada. In their report they minced no words:

> Today much of the west slope is a dog-hair thicket of young pines, white fir, incense-cedar, and mature brush--a direct function of over-protection from natural ground fires. Within the four national parks--Lassen, Yosemite, Sequoia and Kings Canyon--the thickets are even more impenetrable than elsewhere. Not only is this accumulation of fuel dangerous to the giant sequoias and other mature trees but the animal life is meager, wildflowers are sparse, and to some at least the vegetative tangle is depressing, not uplifting.

Dr. Leopold and his committee pointed out this inconsistency and others as well. They recommended a strong course of action, which has since formed the nucleus for a new direction in the management of the wildland parks.

THE LEOPOLD REPORT AND NATURAL LAND MANAGEMENT

> As a preliminary goal, we would recommend that the biotic associations within each park be maintained, or where necessary recreated, as nearly as possible in the condition that prevailed when the area was first visited by the white man. A national park should represent a vignette of primitive America.
>
> Restoring the primitive scene is not easily done nor can it be done completely. Yet, if the goal cannot be fully achieved it can be approached. A reasonable illusion of primitive America could be recreated, using the utmost skill, judgement, and ecologic sensitivity. This in our opinion should be the objective of every national park and monument.

Contrary to an interpretation by some managers, this does not mean turning back the "ecological clock" to some time in the past and then attempting to stop it. It does mean that park managers must view the total park resource mosaic ecologically. It means finding what aspects of the ecosystem need to be rectified (through research) and then doing something about them (through management).

Relatively uninfluenced portions of the parks must be closely guarded and maintained in as pristine a state as possible. To build a road, drill a well, or graze a meadow may accomplish one purpose; however, its effect on the naturalness of the park must also be considered. If an improvement must be made, its disruptive influence must be minimized.

CONTEMPORARY NATURAL RESOURCE MANAGEMENT POLICY

> The National Park Service will manage the natural resources of the national park system to maintain and perpetuate their inherent integrity.

This succinct statement encapsulates the natural resource management mission of the Service. It is accomplished through natural resource planning and management that encompasses all components of the park ecosystem. It is grounded in the philosophy expressed in the Leopold report, which provides a well-conceived and ecologically guided basis for all national park natural resource management activity.

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GUIDING PHILOSOPHY IN FIRE AND VEGETATION MANAGEMENT IN CANADIAN PARKS

Nikita Lopoukhine

ABSTRACT: Although fire was once a major concern to Canadian national park managers, interest in it declined until a new park policy renewed interest in 1979. Early in 1980, when fire management was first proposed, a nearly disastrous fire made managers keenly aware of the need to revise their approach to fire. Resource management priorities and objectives in national parks are determined through the application of a decision process which includes senior management. Understanding the effects of fire on vegetation is a prerequisite to the use of fire. Fire plans must therefore incorporate ecological, evolutionary, and biogeographic factors that are usually derived from the study of vegetation itself. A number of constraints and opportunities affect fire management implementation in Canada's national parks. Although Canadian and American national park policies regarding fire are similar, they differ significantly from those governing provincial parks.

INTRODUCTION

Parks Canada is still in its infancy as far as fire management is concerned. We have yet to enter the implementation phase of fire management and are still at the stage of seeking after wisdom before initiating action. This is in contrast to the situation in the United States, where fire management in wilderness areas is being implemented (Kilgore 1982).

There are a number of reasons why this discrepancy between our two countries exists. The Leopold report (Leopold and others 1963) does not have a counterpart in Canada. In addition, Canada's fire regimes are different and I would suggest more difficult to deal with. The boreal forest's particular fire regime (Kilgore 1982; Alexander and Dubé 1983) which is shared with Alaska has yet to be dealt with in either Alaska's or Canada's wilderness and parks. Furthermore, national parks are administered and perceived somewhat differently in our respective countries. Before describing some of these differences, I will present a historical review of fire management in Canadian parks.

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HISTORICAL NOTES

From the outset, managers of Canada's national parks have been concerned with forest fires. In his annual reports, the First Commissioner of Dominion Parks devoted a section to this topic. The reports included not only details about individuals who have distinguished themselves in fire but also in the size and behavior of fires. In addition, acreages attributed to railroad ignitions were separated from the total acreages burned per year. Through these reports one learns of fire guardians whose job it was to patrol the railways traversing national parks. Also mentioned is the effectiveness of portable (45 lb [≅20 kg]) fire pumps developed by the national parks branch as well as patrols carried out by the Royal Canadian Air Force. Although, historically, fire has been generally considered destructive, early reports had occasional references to its benefits. In the 1926-27 report, subsequent to a "bad" year, the Commissioner wrote "opening up of forest, affording as it does wider and more distant vistas, will be an improvement from the scenic point of view."

For various reasons, the preoccupation with fire waned. Fires were infrequent (for example, Banff National Park had 48 fires between 1880 and 1939 and only 4 between 1940 and 1980 [White 1983]). The late 1960's saw wardens change from patrolers to resource managers; as a result, their interests broadened and the lack of even occasional fires further decreased their interest in fire management. There were exceptions, of course. In Wood Buffalo National Park, fires never ceased to burn. In the 1970's in Jasper, Prince Albert, and Elk Island National Parks fires were prescribed in an effort to maintain or enlarge some representation of prairie ecosystems.

FIRE MANAGEMENT AND RESOURCE MANAGEMENT IN NATIONAL PARKS

On May 19, 1980, the Rolling River Fire was ignited in Riding Mountain National Park. This was just 5 days after the completion of a workshop on fire management in Canada's National Parks and 5 months after Van Wagner and Methven published their Occasional Paper (1980) on the philosophy and strategy of fire management in Canada's national parks. This fire, the fire management workshop, and Van Wagner and Methven's paper are equally important in determining Parks Canada's current approach to fire management.

The workshop was convened to address how best to implement fire management as permitted by the 1979 Parks Canada Policy (Parks Canada 1979). This policy, not unlike one governing national parks in the United States, declares that natural processes such as fire are to be allowed to run their course as long as safety of people, major park facilities, prescribed park values, and good relationships with neighbors are not jeopardized. Also, fires can be introduced into areas where it can be shown that past suppression activity has altered the park's vegetation. Furthermore, whenever active resource management is prescribed, the techniques used will duplicate nature as closely as possible. This policy thus provides a flexible framework that could be tailored to a particular park's situation. The experts in fire management from across Canada and the two invited participants from the United States (R. Mutch and D. Butts) recommended using pilot parks whereby lessons learned could be transmitted to others.

Earlier that year, Van Wagner and Methven had introduced the concept of the negative exponential curve to vegetation management in national parks and suggested ignoring the cause of a fire and instead concentrating on fire's effect. As much as the cause of a fire may seem important to a manager vested with the responsibility of maintaining natural conditions, it is essentially a moot point. The manager is not managing ignitions but effects. The projected effect of a fire must fit into existing vegetation plans before being permitted to burn.

The fire in Riding Mountain National Park, because of an unexpected weather system, burned 50,400 acres (20 400 ha) in 6 days, thus demonstrating how far we had let fire control slide. Safety precautions were abandoned, logistics broke down, and lives threatened, although luckily none were lost. In spite of having an approach and a guiding philosophy, we were obviously not prepared to control fire. As a result, Parks Canada is concentrating on upgrading its fire control capabilities. Once this is achieved, fire management can finally begin.

Whenever fire management will be initiated in a national park, it like all natural resource management initiatives, will pass through the Natural Resources Management Process. This process feeds into and reflects objectives set out by a park management plan, which is the principal product of the National Park Management Planning Process. Key preliminary steps of the process consist of an ecologically integrated inventory followed by an analysis that identifies the park's biotic and abiotic elements, as well as natural processes that are critical to the integrity of a park's natural resource system. A conservation plan is then drawn up; it sets priorities and determines costs of implementation. Individual management plans are then drafted.

Fire management plans are designed to achieve objectives formulated for natural resource management. Thus, any fire management plan will be a part of a management plan addressing an issue raised in the Conservation Plan.

VEGETATION MANAGEMENT

Historically, in comparison to wildlife, Canada's national park managers have considered vegetation a secondary resource. Vegetation was seldom high on a manager's list of concerns. Usually vegetation considerations began and ended in the context of wildlife habitat, a camper's experience, or the landscape architect's use of exotics. Although rare plants and certain other plant communities have generated interest, management techniques in such cases have consisted of directing park visitors away from specific sites. Active management (other than suppressing fire or eradicating exotics) has been rare, and an attitude of benign neglect has generally prevailed.

Introducing fire to national parks, however, moves vegetation management into a primary position. Placing a high priority on vegetation plans is critical because past suppression policies have significantly altered vegetation patterns. Consequently, fire's natural role must be reflected in any fire management plan. The difficulty, of course, is in defining what fire's natural role is.

VEGETATION PLAN CONSIDERATIONS

Natural vegetation! This is the objective of vegetation managers for national parks. Van Wagner and Methven (1980) define it as "a native vegetation in the best equilibrium with the natural environment." A natural regional environment is defined as one in transition, its direction is determined by the unfettered interplay of forces and elements. It follows that by striving for a free interplay and the exclusion of exotics, a manager will ensure a "natural" vegetation. Because wildlife is generally vegetation-dependent, a "natural" wildlife complement will also be ensured. The key to all of this is the free interplay of forces and elements or natural processes.

To determine the role of fire as a natural process, managers must first examine the vegetation that is affected by it. Our records of vegetation are not sufficiently reliable to be used solely for this purpose. The vegetation of a park must be considered in the context of ecological, evolutionary, and biogeographical parameters and within a temporal and spatial framework. Essentially, determining what is natural vegetation requires translating historical and current patterns into a series of future scenarios. It is important to recognize that such scenarios should consist of a range of possibilities because of the vagaries associated with most natural processes affecting vegetation in Canada. Also, the impacts associated with such processes are often severe and usually drastically alter the vegetation mantle of a given area.

Rowe (1983) cautions that fire is not the sole process affecting vegetation. Herbivores, geomorphic processes, and climate elements (wind, temperature, and precipitation) must also be included in vegetation plan considerations. Fire, however, can effectively overwhelm the influences of all these processes. Conversely, fire may in part depend on other factors to determine fuels and create conditions that influence the vegetation mix of an area.

The issue is complex, and the challenges are many. For instance, fundamental questions related to wildlife-vegetation relationships, effects of variable fire intensities, migration trends, as well as evolutionary adaptations, should be answered before they can be considered in vegetation plans. At this time, one plausible approach within fire-dependent ecosystems is to match the negative exponential curve model (Van Wagner 1978) with the age-class distribution of forest stands. Because the regrowth after a fire consists primarily of those species that previously occupied the site (Van Wagner 1983; Kelsall and others 1977), species should not be a concern. The focus should instead be on the intensity, depth of burn, and timing of the fire in relationship to a particular species' phenology or fire adaptation characteristics because these features will determine the relative abundance of a species after a fire. For objectives related to wildlife management this information is crucial and, unfortunately, not always available.

CONSTRAINTS ON FIRE MANAGEMENT

Fire management is always affected by a series of constraints. These constraints do not necessarily hinder fire management, but they do influence decisions concerning when and how to use fire.

Parks Canada Policy

Although Parks Canada policy acknowledges that fire is a natural process and therefore should be permitted to run its course in national parks, it also limits its use. For instance, fires are to be suppressed if neighboring lands, public safety or health, and/or major park facilities are threatened. Also, if a particular park value is threatened by fire then manipulation of a natural process is justifiable.

Attitudes

Canadians have recently been sobered by the realization that although their nation is supposedly blessed with infinite resources, its wood supply is running out. Awareness of this problem may produce an outcry against "needless" burning of valuable and now scarce timber. Nevertheless, changes in attitudes toward fire and firefighting are occurring. Suppression strategies and control measures based on values at risk and likelihood of success is replacing blanket attacks on all fires. Rationale for burning are increasingly based on ecological principles. These changes will undoubtedly wear down any internal resistance based on a fear of external criticism.

The general public has been influenced by the familiar U.S. Smokey Bear and by similar provincial and federal advertisement campaigns. These efforts have convinced most Canadians that fires are unwanted. Until the public is made aware that there are also benefits associated with some fires, this attitude of fires being bad will constrain actions of fire managers in national parks.

Further, commercial establishments including townsites associated with some of our parks and the holders of special rights, such as subsistence harvesting, can be directly affected by fire management activities. Because Parks Canada recognizes these rights and permits the existing commercial establishments, they are obligated not to jeopardize either through fire management activities.

Knowledge

The attitude constraint can be alleviated through the dissemination of knowledge; however, an inadequate knowledge base is a constraint in itself. The need for research is commonly lamented, yet there are a finite number of researchers and fiscal resources, whereas knowledge gaps appear to be infinite. Without its own complement of researchers, Parks Canada must stand in line for researchers' time. In addition, these researchers' efforts are increasingly directed toward economically tangible problems. Our pristine outdoor laboratory attracts few researchers, and our sometimes less than cooperative attitude has been discouraging to them.

Parks Canada's knowledge of fire control lags behind the state-of-the-art. The 1980 Rolling River Fire in Riding Mountain National Park drove this fact home. Three years later we are beginning to put together the mechanisms by which Parks Canada staff will be better prepared to deal with similar instances of wildfires.

OPPORTUNITIES

The implementation of the Parks Canada fire policy is facilitated by a number of opportunities available to managers.

Parks Canada Policy

Parks Canada policy acknowledges the importance of fire as a natural process. This is significant for managers because the policy also obligates them to avoid interfering with this process whenever possible and to reinstate this process in areas where it was suppressed. The policy further states that whenever resources must be actively manipulated, the method used should emulate nature. Fire provides the best opportunity to do just that.

National Park System

Canada has 10 forested regions (Rowe 1972) and 2 non-forested regions. There are 29 national parks distributed among these regions. The Boreal Forest Region, the largest, contains 10 national parks. The opportunity exists in this region to preserve within these parks particular segments and ecotypes of the boreal forest by using fire in accordance with its locally established role. Such measures preserve the diversity of Canada's forested region.

Furthermore, some of the boreal forest parks are large or remote or both and thus provide an excellent opportunity for the unencumbered use of fire. Such opportunities alleviate the particular concern of having the characteristic high-intensity fires of the boreal forest escape the limits of a park (Alexander and Dubé 1983). These parks are large enough to permit a relatively natural role of fire to be invoked without concerns of neighboring landowners.

Canada's Fire Management Community

The fire management community's involvement in Parks Canada's aspirations for fire management continues to inspire park managers. Seeking little in return, this community has assisted in staff training and firefighting and has guided us in defining the role of fire in park's ecosystems. Their constructive criticism is leading to the upgrading of fire management capabilities within national parks.

The goodwill expressed by the fire management community toward Parks Canada is an incentive for park managers to incorporate them into all fire management initiatives. At the same time Parks Canada has ensured its own participation in this community by sitting as a member of the Canadian Committee of Forest Fire Control and contributing to the Canadian Interagency Fire Centre.

United States Fire Community Initiative

United States leadership in wilderness fire management is a particular incentive and role model for park managers in Canada. There is little doubt that the progress shown in Canada's parks is due to the changes policy in the United States that were inspired by the Leopold report (Leopold and others 1963). The influence of United States personnel at the workshop previously mentioned and our participation in symposia such as this one are also noteworthy influences.

A Comparison Of Park Policies

There is little difference between Canadian and U.S. National Parks fire policies, particularly since human-caused fires are now being permitted to burn in certain United States national parks under specific conditions (Kilgore 1982). Thus our previous major difference is evidently eliminated.

In contrast, the difference between the policy of provincial parks and national parks is varied and vast. Recognizing fire's role as a renewal agent is not likely to be included in fire policy in Alberta (Smith 1983), and British Columbia does not recognize the existence of natural "wanted" fire (Doerkson 1983). On the other hand, both foresee the eventual use of prescribed fires with deliberate scheduled ignitions. In fact, in British Columbia it is feasible to use fire to manipulate plant succession in order to meet park ecological objectives. Other provinces, such as Saskatchewan, New Brunswick, and Quebec, have excluded the possibility of fires from provincial parks where parks are considered an integral part of the forest resource (MacAuley 1983; Barr 1983; LeBlanc 1983). Newfoundland does not wish to risk interrupting recreational uses of parks (Hustins 1983), and Alberta managers have stated that some parks were either too small or had facilities that could not be risked (Smith 1983). Nova Scotia (Graham 1983) and Manitoba (Briggs 1983) as a rule suppress all fires in parks, as does Prince Edward Island. On Prince Edward Island, however, on a small, 10-acre (4-ha) natural reserve 0.1 acre (¼ ha) will be burned annually or biannually to maintain an early succession state (McAskill 1983). Ontario's approach is much like that of Canada's national parks, which recognizes fire's role while continuing to suppress most fires (Alexander and Dubé 1983).

CONCLUDING REMARKS

Canada's national parks will celebrate their centennial in 1985, 13 years after the United States parks celebrate theirs. Canada adopted a policy favorable to fire management in 1979, 11 years after the United States parks changed their policy. A definite follow-the-leader trend exists and the time lag is significant. It is conceivable, however, that Canadians will begin to close the gap when faced with resolving fire management issues in our boreal forest parks. Cooperative efforts may also play a role in resolving such issues as the relationship of fire to insect outbreaks such as that of the mountain pine beetle in Glacier-Waterton National Parks Lakes or spruce budworm in the East.

Ensuring that fire management in national parks produces natural results requires a definite standard and a commitment. Half measures are not acceptable. The next few years are critical because experimenting will take place, the costs of fire management will be estimated, and an ambitious strategy will be proposed. The potential controversy associated with each of these facets could curtail the advancement of fire management. Because there is a commitment to Parks Canada to natural processes and a continued commitment by Canadians to natural area preservation, there are no alternatives to fire management. It is inevitable.

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245 THE PRESCRIBED FIRE AND FIRE EFFECTS WORKING TEAM: WHAT IS IT? 11

William L. McCleese

ABSTRACT: The National Wildfire Coordinating Group (NWCG) is an organization of State and Federal fire management services representatives. It was formed to coordinate the fire programs of the participating agencies and thus to enable each agency to execute more effectively its fire management programs.

INTRODUCTION

The National Wildfire Coordinating Group (NWCG) established the prescribed Fire and Fire Effects Working Team in 1977. It was the first working team that did not have fire suppression as its principal interest. Instead, its mission is to coordinate the multiagency effort of prescribing fire to achieve management objectives. This is accomplished through technology transfer, establishing job qualifications and standards, identifying necessary working tools, and evaluating the performance of prescribed fire and smoke management programs.

MEMBERSHIP

The team consists of representatives of agencies belonging to the National Wildfire Coordinating Group. Members are chosen for their interest and expertise in prescribed fire. An attempt is also made to choose members for each major national geographical area.

Current Team Members

Bill McCleese Chairperson	USDA Forest Service Prineville, Ore.,
Fernando Abeita	Bureau of Indian Affairs Albuquerque, N. Mex.
Larry Bancroft	National Park Service Three Rivers, Calif.
Gardner Ferry	Bureau of Land Management Portland, Ore.
Bob Mutch	USDA Forest Service Missoula, Mont.
Barritt Neal	California Dept. of Forestry El Cajon, Calif.
Hugh Ryan,	South Carolina Forestry Comm. Columbia, S.C.
Jan van Wagtendonk	National Park Service El Portal, Calif
Frank Zontek	Fish and Wildlife Service St. Marks, Fla.
Mike Miller	NWCG liaison representative State Forester of Oregon

ACCOMPLISHMENTS

The following are team accomplishments over the past 6 years:

1. Development and publication of the "Prescribed Fire Job Qualification Guide," which defines the skill and knowledge requirements of key prescribed fire management positions. Elements of this guide have been adopted by several Federal and State agencies.

2. Input to the Society of American Foresters Glossary of Prescribed Fire Terminology.

3. Updating prescribed fire information in FIREBASE.

4. Sponsoring interagency workshops, including this symposium.

5. Developing and publishing the "Prescribed Fire Monitoring and Evaluation Guide."

6. Publishing a brochure that lists prescribed fire training sessions and meetings planned by universities and Federal and State agencies during the coming year.

Paper presented at the Wilderness Fire Symposium, Missoula, Mont., November 15-18, 1983.

William L. McCleese is Forest Supervisor of the Ochoco National Forest, USDA Forest Service, Prineville, Ore.

PROJECTS

Current Projects

1. Development of a "Smoke Management Guidebook." This guidebook, to be published in 1984, is for the field practitioner, burn boss, and prescribed fire manager who plan and conduct burns. Although its focus is national, it contains supplementary regional information. It provides practical guidelines for managing prescribed fire to achieve smoke management objectives. Leading smoke management and prescribed burning experts from many agencies across the country are contributing to its development.

2. Publication of a "Burning Plans Guide." This guide will provide a suggested outline of essential elements of burning plans, plus several examples of burning plans in use by agencies in various parts of the country.

3. Cosponsorship of a Prescribed Fire and Aerial Ignition Workshop to be held in October 1984. The Prescribed Fire and Fire Effects Working Team will join the Intermountain Fire Council and the Fire Effects and Use R&D Program of the Intermountain Forest and Range Experiment Station in a workshop focusing on the practical aspects of prescribed burning and aerial ignition.

4. The team is preparing to provide input to the national, interagency prescribed fire and smoke management training program at the National Advanced Resource Technological Center (NARTC). We will suggest courses, subject matter, and sequence of courses, and select instructors and steering committee members.

Future Projects

The team's long-term project will be to develop a "Prescribed Fire Notebook," a practical field guide for prescribed fire practitioners. Our "Job Qualification Guide," "Monitoring and Evaluation Guide," and "Smoke Management Guide" will become chapters of this volume.

From this discussion of past, present, and future activities you can see that the team has concentrated on helping the prescribed fire practitioner and program manager do a better job of applying prescribed fire in a professional and competent manner. We firmly believe that the entire fire management community is in this business together; our success will depend on the quality of the program as the public perceives it, regardless of who lights the match.

We would be pleased to receive your suggestions on future projects and priorities. We want to respond to your needs.

Section 2. Fire Management Policy and Programs

INTRODUCTORY REMARKS--FIRE MANAGEMENT POLICY AND PROGRAMS

Edward G. Heilman

Fire management policy, which basically directs agencies as to what to do in fire management, continues to evolve. It is not static and can and should be changed as social and political needs change, as additional scientific information becomes available, and as mistakes are made and evaluated. The speakers in this session describe various State and Federal agency fire management policy applications and implications.

The formation of agency policy ideally begins with concerns of the landowner, who is usually defined as the Federal or State government or the local public, depending on the area being considered. The public, through their elected representatives, enacts laws and regulations that both require and limit agency activities. Within these legal limits agencies define and specify their policies, ideally with public input. At this stage, scientific findings can have a significant role. Following policy determination, agencies then implement these policies within available budget limitations. Again ideally, managers then evaluate this implementation, and finally review and change agency policies if necessary.

Paper presented at the Wilderness Fire Symposium, Missoula, Mont., November 15-18, 1983.

Edward G. Heilman is Staff Director, Aviation and Fire Management, Northern Region, U.S. Department of Agriculture, Forest Service, Missoula, Mont.

For this series of events to occur, however, there must first be an identified need for change and, of course, the opportunity to change. As an example of such change, the U.S. Department of Agriculture, Forest Service, in 1978 changed its previous all-out fire suppression policy, which began in 1935, to a more flexible policy allowing a variety of strategy responses such as confinement or containment as well as control.

Fire management policies specific to wilderness have also evolved over the years and should continue to do so. Scientific knowledge has played a significant role in present policy development, but even within the scientific area there are gaps and some disagreement--on the human health effects of wood smoke, for instance. The major unresolved policy in wilderness fire management, however, is economics. Unresolved economic questions will undoubtedly have a major bearing on the evolution of fire management policy.

FIRE MANAGEMENT OPPORTUNITIES AND CONCERNS UNDER BLM WILDERNESS PROGRAM POLICY

John E. Birch

ABSTRACT: The Bureau of Land Management (BLM) has substantial public lands under wilderness consideration in Wilderness Study Areas (WSA); none have been designated as wilderness. Because of this, primary emphasis in BLM wilderness fire management has been to prevent impairment of wilderness values rather than to develop and implement fire management plans. To date, this emphasis has been related primarily to limitations on types of fire control equipment and methods. Few BLM fire management plans allow the use of fire in WSA's. WSA's in the BLM are relatively small and contain fuel types susceptible to rapid rate of fire spread. These factors, along with the limited funds, will cause BLM to be relatively slow in developing an extensive natural fire program for wilderness areas in BLM.

INTRODUCTION

Title IV of the Federal Land Policy and Management Act of 1976 (FLPMA) designated specific management areas of public lands to be administered by the Secretary of the Interior through the Bureau of Land Management (BLM). In addition to designating two National Conservation Areas, the act mandated a review of public lands having wilderness characteristics, as described in the Wilderness Act of 1964. Subsequent to the review, the Act requires occasional reports and recommendations on inventoried areas as to suitability or nonsuitability for designation and preservation as wilderness.

After BLM's wilderness inventory, 800 WSA's and Instant Study Areas (ISA) were created; together they comprise 23 million acres (9.3 million ha) in 11 western States. These areas are now under review for suitability or nonsuitability. The largest acreages and number of areas are in California, and the next largest acreage is in Nevada. As we discuss fire management in these areas, keep in mind the size and location, which will affect how fire can be managed.

Paper presented at the Wilderness Fire Symposium, Missoula, Mont., November 15-18, 1983.

John E. Birch is Chief, Division of Fire and Aviation Management, Bureau of Land Management, U.S. Department of the Interior, Washington, D.C.

There is a distinct difference in fire management, as well as in other land management programs, as administered in WSA's designated by the BLM and as administered in wilderness areas included by Congress in the wilderness system. Philosophical differences produce some differences in planning and managing fires in the two types of areas. The emphasis in a WSA is to retain wilderness values so that it may eventually be considered for inclusion in the wilderness system. On the other hand, a designated wilderness area has specific management objectives, such as maintaining or restoring a fire-dependent ecosystems or reintroducing a natural fire regime into an area. Our major challenge or opportunity thus becomes to develop objectives and procedures that meet the present needs of study areas and that later can be incorporated into the fire management component of wilderness management plans.

POLICY

The central theme of fire management in BLM WSA's is that suitability for wilderness will not be impaired. Within this broad principle, Bureau policy permits a variety of fire management options, varying from full suppression to the use of fire to achieve wilderness objectives.

Generally speaking this policy, which provides guidance for preserving WSA's, has been implemented on the ground by BLM field offices. District offices identify WSA's in their fire suppression plans and on their fire dispatch maps and then tailor initial attack methods and strategies to minimally affect wilderness values. These strategies are provided for in dispatch system plans.

Planning for minimal impacts may include requiring vehicles to be driven only on existing roads and trails, restricting cross-country travel to places where soil or vegetation damage will not occur, prohibiting helicopter landings except in existing openings, restricting fugitive marker dyes in retardants, and in most areas, using a resource advisor during suppression operations and subsequent cleanup. Most of this process is in our Bureau directive on Interior management policy and guidelines for lands under wilderness review. Based on our inquiries, it appears that most of the BLM field offices' fire and wilderness staffs are satisfied with these policies and procedures as implemented for suppression actions in WSA.

The Bureau policy in wilderness areas is that all fire normally will be controlled to (1) prevent the loss of human life or property in the wilderness or (2) prevent the spread of fire outside the wilderness areas where human life, property, or resources may be threatened. In suppressing fires, we use the methods and techniques least likely to impair wilderness values while achieving wilderness objectives. This policy emphasizes limited use of heavy equipment such as dozers. Instead we construct lines using hand crews, use black lines, and so on; that is we usually do not use earth-moving equipment except in crises.

The BLM wilderness policy recognizes the role of natural fire. The policy further states that natural fire, or lightning-caused fire,[1] is part of wilderness ecology. We also have a policy that <u>all</u> fires, natural or human-caused, will be aggressively suppressed unless the area concerned is covered by an approved fire management plan; that is, a plan that in part provides for the role natural fires will be allowed to play in the ecosystem.

Past suppression programs in BLM as well as in other wildland areas have significantly changed some naturally fire-dependent ecosystems. Fires in these areas would not follow a "manual" course of action and thus these areas require natural fire, allowed and managed, under approved management plans.

BLM policy allows prescribed burning in wilderness to achieve wilderness management objectives. Prescribed burning, ignited by Bureau personnel, may be allowed on a case-by-case basis when it is to reintroduce or maintain the natural condition of a fire-dependent ecosystem. This policy permits us to:

1. Restore fire where past fire management practices have interfered with and changed the natural ecological process.

2. Perpetuate a primary value of a specific wilderness area.

3. Perpetuate a threatened or endangered species.

4. Perpetuate and maintain livestock operations if prescribed fire was used on the site before the wilderness designation.

The wilderness management policy that applies specifically to designated wilderness areas directs such fire management activities as presuppression, detection, suppression methods, building structures, removing evidence of fire suppression actions, and restoring damage caused by fire control, as well as developing fire management plans. In all these activities the emphasis is protection and preservation of wilderness values.

PROGRAM CONCERNS

Although the BLM has experienced few or no problems with escaped natural fires or severe damage to wilderness values because of wildfires, certain inherent problems and concerns are becoming apparent in the management of the program. First, as previously indicated, there is a difference between Wilderness Study Areas as administratively designated by the BLM and wilderness areas as legislated by Congress for inclusion in the wilderness system. Currently, no BLM Wilderness Study Area has been placed in the National Wilderness Preservation System, although the Aravaipa Canyon in Arizona has been recommended for inclusion. Until some areas are taken from study status and designated as wilderness, there will be some delay and possibly problems in establishing a natural prescribed fire program in the BLM. Our major challenge will be to develop objectives and procedures to meet the needs of the wilderness areas and later to incorporate these into the wilderness management plan as the fire management component.

To date few, if any, fire management plans have been developed that allow natural fire in WSA's. There are two main reasons for this. First, fire staff sizes and workloads generally preclude rapidly developing a large number of plans--we just do not have the capability. I feel, however, that time and need will change this workload priority. Second, the overriding fire policy guidance calls for control of all fires that threaten resources or property. This policy has made people reluctant to allow fires to continue to burn--they feel most fires should not be allowed to burn without attempting suppression.

BLM will not develop an extensive natural fire program for WSA's because the designation is temporary. We do not need an extensive natural fire program to meet our objectives; that is, to prevent impairment in WSA's and prevent unnecessary loss due to wildfire. BLM will have to develop fire management plans for all wilderness areas shortly after they are designated. It is BLM's intention to develop a management plan for each wilderness area within 2 years after designation; fire management plans will be an essential component of these overall management plans.

Thus far, no prescribed burning has been done in the WSA's for several reasons, nor do we anticipate doing a significant amount of such burning in the near future. This decision is based primarily on the availability of funds and the capability required for planning and execution; with our present capability all we can do is keep up with other resource programs such as forestry and range and wildlife management in high priority management areas.

[1] Editors' note: please refer to the <u>Foreword</u> for comments on prescribed terminology.

Another concern arises in our wilderness fire management program because the WSA's are small and contain fuel types susceptible to rapid fire spread. As mentioned before, the wilderness areas have some 23 million acres (9.3 million ha) in over 800 separate units, which roughly works out to be an average 28,750 acres (11 635 ha) per wilderness area, a relatively small size compared to what many perceive as wilderness. Almost half this area is in the States of California and Nevada. Because most WSA's consist of vegetative types that facilitate the rapid spread of wildland fires and increase the potential of fires to escape unit boundaries and damage resources and improvements on adjoining lands, a fire that burns 15,000 to 20,000 acres (6 070 to 8 094 ha) in one burning period is not unusual. Obviously, such a fire is likely to affect the vegetation in a significant portion of a wilderness area and to escape the boundaries of the areas. The combination of relatively small areas and light, flashy fuels therefore made BLM reluctant to consider natural programs in WSA's, particularly in the areas previously described, which can be affected so significantly with but one fire.

FIRES IN BLM WILDERNESS STUDY AREAS

Our limited experience with fire in WSA's has not presented us with any great problems up to this point. As stated before, the BLM is still suppressing fires in WSA's with a number of limitations on suppression methods and techniques. Only limited problems have developed in the recent past, and many of these occurred when BLM management objectives conflicted with our various protection contractors' "historic" ways of suppressing fires. These problems have been overcome, for the most part, through mutually agreed upon modifications of suppression tactics; however, getting contractors to change has increased protection costs. Except for the additional costs, no particular problems in suppressing fires were identified. Most responses from the field indicated that limiting suppression methods and equipment kept damage to wilderness values and the need for subsequent rehabilitation to a minimum. This past season we had a fire burn 2,000 acres (≅800 ha) in a WSA in eastern Oregon. The only problem associated with it was in-house management concerns, rather than problems of technology or suppression strategy.

SUMMARY

Although a substantial amount of BLM acreage is under wilderness consideration, few areas to date have been nominated for wilderness status. Because of this, the primary emphasis in the overall wilderness fire management program has been to preserve wilderness values. Generally, this goal has led to limitations on types of fire control equipment and methods. Few BLM management plans permit the use of fire in meeting management objectives. Those WSA-related plans that have been produced generally call for aggressive suppression with restrictions on suppression methods. There are also concerns about BLM's capability and need to produce a large number of fire management plans permitting fire use in WSA's. These considerations, combined with the presence of many small, proposed wilderness areas containing flashy fuel types will make BLM relatively slow to develop extensive natural fire programs for Wilderness Study Areas.

245 FIRE MANAGEMENT POLICY AND PROGRAMS FOR NATIONAL WILDLIFE REFUGES

Fitzroy A. Belcher

ABSTRACT: The U.S. Department of the Interior, Fish and Wildlife Service (FWS), is committed to a strong fire management policy. This policy is that the agency recognizes wildfire and prescribed fire as the only two kinds of fire. Wildfire is suppressed aggressively, and prescribed fire is used to manage habitat and resources and to achieve refuge objectives delineated in established refuge management plans. Many refuges depend entirely upon cooperative agreements and contracts for fire suppression. FWS policy is that the agency will depend upon their coop agreements and contracts whenever possible rather than build a large internal fire suppression organization.

The Fish and Wildfire Service (FWS), like the Bureau of Land Management and the National Park Service, is part of the U.S. Department of the Interior. Therefore, FWS fire management policy must be and is consistent with departmental policy.

Basically, FWS policy states that there are only two kinds of fire: wildfire or prescribed fire. Wildfires are aggressively suppressed unless the fire is in an area included in an approved plan that calls for less than total suppression. Less than total suppression is termed "modified suppression," which may vary in intensity from anything less than total suppression to simply monitoring the fire. The decision to designate a modified suppression area is based on the cost of suppression and value of the resource. Decisions involving strategies in controlling wildfires (such as allowing the fire to burn out from natural barriers rather than using a more direct or indirect attack) are not considered modified suppression because they are not included in a preapproved plan.

The National Wildlife Refuge System is comprised of some 400 refuges having 86.7 million acres (35.1 million ha), 141 Waterfowl Production Areas with 1.6 million acres (648 000 ha), and an additional 0.4 million acres (≅162 000 ha) in Coordination Areas. The National Wildlife Refuge System contains 72 wilderness areas having 59,189,731 acres (≅2 400 000 ha). Fire management activities in wilderness areas are the same as for the rest of the refuge system, with the following exceptions: Low impact suppression techniques and equipment are preferred for wilderness areas. Any suppression technique and equipment is authorized, however, when necessary to suppress the fire. The use of prescribed fire as a tool to enhance and protect wilderness and unique ecosystem values is authorized and encouraged.

Prescribed fire is used to achieve refuge objectives. All ignitions, both planned and unplanned,[1] are acceptable when in prescription. The prescriptions for planned ignitions and unplanned ignition are identical except for source of ignitions and firing sequence. All of the fire environment factors must be met; these include windspeed and direction, temperature, relative humidity, fuel moisture, soil moisture if applicable, season of year, and drought factors. The prescription must also state precisely what the fire should accomplish.

Fire management planning is required for all units of the refuge system. Fire plans range from a justification statement that no plan is required to comprehensive plans for suppression and prescribed fire. Many refuges depend entirely upon cooperative agreements and contracts for fire suppression. FWS policy is that the agency will use interagency agreements and contracts rather than build a separate fire suppression organization.

Prescribed fire is used throughout the system as a management tool to enhance and protect habitat and resources. The following examples illustrate the extent of this use:

In Merritt Island National Wildlife Refuge in Florida, fire is being used to decrease 20+-year-old fuel loadings. Large blocks (3,000 to 5,000 acres [≅1 200 to 2 000 ha]) are aerially ignited; some 15,000 to 20,000 acres (≅6 000 to 8 000 ha) are burned each year to develop a mosaic on which suppression actions can safely be taken.

In Piedmont National Wildlife Refuge in Georgia, fire is used intensively to manage pine stands and to develop habitat that encourages the production of quail, turkey, and deer.

In coastal Texas on Brazoria National Wildlife Refuge, fire is used in marshes to provide habitat for the endangered whooping crane.

Paper presented at the Wilderness Fire Symposium, Missoula, Mont., November 15-18, 1983.

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[1]Editors' note: Please refer to the Foreword for comments on prescribed fire terminology.

In Arrowwood National Wildlife Refuge in North Dakota, fire is used on grasslands, mixed grasslands, and brush to maintain mallard duck nesting habitat and production.

Fire is used in Malheur National Wildlife Refuge to maintain marsh waterfowl nesting habitat and to manage grassland for waterfowl and livestock.

Fire is being used in Alaska National Wildlife Refuges in areas designated for limited or

In Arrowwood National Wildlife Refuge in North Dakota, fire is used on grasslands, mixed grasslands, and brush to maintain mallard duck nesting habitat and production.

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FIRE MANAGEMENT POLICY AND PROGRAMS FOR BIA-ADMINISTERED WILDERNESS

Charles W. Tandy

ABSTRACT: This abbreviated history of significant dates and congressional actions provides insight into the development of fire management policies and programs for wilderness lands under the jurisdiction of the U.S. Department of the Interior, Bureau of Indian Affairs (BIA). The BIA works with 498 Indian tribes, and the Indian lands for which it is responsible are private lands. Only recently have these tribes begun to operate reservation programs.

Before I begin my discussion of fire management policy and programs for wilderness administered by the U.S. Department of the Interior, Bureau of Indian Affairs (BIA), I feel it is appropriate to outline some significant Bureau of Indian Affairs history. I believe this information will explain why BIA wilderness fire management policy and programs may vary considerably from those of other Federal or State agencies.

1763: Proclamation of King George III, which attempted to keep settlers east of the Appalachian Divide and established an "Indian Country" or "reserved lands" not available for purchase from the Indians.

1775: Continental Congress assumed control of Indian Affairs; Indian Commissioners were given authority to negotiate treaties with Indians.

1786: The Secretary of War was made responsible for Indian Affairs by an Ordinance of August 7th.

1789: The new Constitution gave Congress authority "to regulate commerce with foreign nations, and among the several States, and with the Indian tribes" (emphasis added).

1803-1806: The Lewis and Clark Expedition contacted many additional Indian tribes as it explored the region from the Mississippi River to the Pacific Ocean.

1824: The Secretary of War created a Bureau of Indian Affairs within the War Department.

1830: Indian Removal Act passed by Congress established procedures for exchange of eastern Indian lands for new western acreage. In other words, removed all Indians living east of the Mississippi River to new western lands.

1849: By Congressional action the Bureau of Indian Affairs was transferred from the War Department to the new Department of the Interior.

1868: The Indian Peace Commission negotiated final treaties with Indians; the last of the 370 treaties was with the Nez Perce on August 13, 1868.

1887: The General Allotment or Dawes Severalty Act made the allotment of land to individual Indians and the breaking up of tribal landholdings the official policy of the United States. Congress felt that by providing individual ownership of small pieces of land it would help the Indians become "self-supporting."

1902-1910: Beginning of Federal Indian reclamation, forestry, and conservation programs.

1924: Congress granted citizenship to all Indians. The majority were already citizens as a result of treaties or earlier blanket grants to particular groups. (Indians did not gain the right to vote in all States, however, until 1948.)

1934: The Wheeler-Howard or Indian Reorganization Act officially reversed the trend to break up tribal governments and landholdings. This Act provided for tribal self-government, ending the practice of allotting land to individual Indians, and instituted modern conservation and resource development policies.

Early 1950's: The Hoover Commission's termination policy unilaterally terminated the Federal government's trusteeship responsibilities with Indians. The first tribe to be terminated was the Menominees of Wisconsin; this was followed by the termination of the Klamaths and other smaller tribes. This policy continued through the 1960's.

1970: President Nixon ended the Federal government's unilateral termination policy, reaffirmed the special relationship between the Federal government and Indian tribes, and set the stage for Indian self-determination.

1974: Indian Self-Determination and Education Assistance Act (PL 93-638). This Act encourages each tribe to administer BIA reservation programs. Under the Act, Federal contracting requirements are modified to give tribes greater opportunity to direct and operate reservation programs with funds provided under contract with the BIA.

Paper presented at the Wilderness Fire Symposium, Missoula, Mont., November 15-18, 1983.

Charles W. Tandy is BIA Director, Boise Interagency Fire Center, Boise, Idaho.

What has this to do with fire management policy and programs for BIA administered wilderness? I believe the relevance of this historical review to fire management is indicated by the following.

1. The Indian Service was initially a diplomatic service to manage negotiations between the United States Government and the Indian tribes. Through jurisdictional aggrandizement and the tribe's voluntary surrender of tribal powers, the Indian Service subjugated nearly every aspect of Indian life to the discretion of its officials. Only in recent years have tribes been given the opportunity to direct and operate reservation programs.

2. The Bureau of Indian Affairs does not deal with one group of people as other Federal agencies do. As I have indicated, 370 treaties have been signed. The BIA, working with tribal governments, provides services and programs to Indians and Alaskan Natives associated with 498 different tribes and Alaska villages. When considered as government-to-government relationships, this means working with 498 nations.

3. Probably most important, the Indian lands the BIA protects and manages are private lands.

INDIAN WILDERNESS AREAS

In 1937, the Commissioner of Indian Affairs, John Collier, signed an order drafted by then Chief Forester for the Office of Indian Affairs, Bob Marshall. It established 12 roadless areas with 4 wild areas on 12 reservations across the country. The order was similar to the Federal Wilderness Act of 1964 in that it preserved untouched land for future generations. The only management restriction was no roads in these areas were to be passable to motorized vehicles.

Between 1958 and 1960, all but two of the 16 roadless and wild areas were declassified. Only the Wind River Roadless Area on the Wind River Reservation in Wyoming still exists. The areas were declassified for two reason: they were created without the consent or input of the tribes involved, and many of the tribes wanted to develop the areas for economic reasons.

In 1970, through Public Law 91-550, Congress transferred the Rio Pueblo de Taos watershed (the 48,000-acre [19 400-ha] Blue Lake Area) of the Carson National Forest from the Department of Agriculture to the Department of the Interior to be part of the Pueblo de Taos Reservation. As a result, this area is held by the United States in trust for the Pueblo de Taos and is the only wilderness area under Bureau of Indian Affairs jurisdiction that is to be maintained in accordance with section 2(c) of the Wilderness Act of 1964.

Although only this area was established by the Wilderness Act, several tribes have designated tribal wilderness or primitive areas. Activities and constraints applicable to these tribal wilderness areas are outlined in various tribal plans or resolutions. These constraints guide BIA management of fires in these tribal wilderness areas.

By now it should be apparent that the Bureau of Indian Affairs does not have a national policy concerning fire management in wilderness areas. Fire management policy for wilderness areas is reservation or agency specific. Wilderness fire plans allow fire to play a natural role in ecological processes, with the overriding qualification that all fires threatening human life or property or having the potential to spread outside the designated wilderness area will be suppressed by methods causing the least damage to the environment.

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FIRE MANAGEMENT POLICY AND PROGRAMS FOR CALIFORNIA'S STATE PARK SYSTEM

Maurice H. Getty

ABSTRACT: Prescribed fire is receiving increased emphasis in the California State Park System and has been used for resource management purposes for over 10 years. The prescribed fire program during this period has concentrated primarily on training personnel and on conducting training burns. Now, with a cadre of trained personnel, a 5-year fire program has been instituted in about one-third of the units where fire will be beneficial. The major purpose of the program is to reintroduce fire as a natural process in the diverse ecosystems within the Park System units.

INTRODUCTION

The California Department of Parks and Recreation manages over 1.1 million acres (445 000 ha) of land, which is divided among more than 250 units. These units are distributed throughout the state and are representative of California's great cultural and natural diversity. They range from small historic units in urban settings to large coastal, mountain, and desert tracts of land that are still relatively undisturbed.

The classifications, purposes, and resource management objectives for these units are as diverse as their sizes and locations. Management regulations and philosophies differ greatly in those units classified in the broad category of State recreation units, which includes State beaches, as compared to those units designated as State parks, State historic parks, and State reserves. Even within State recreation areas and State beaches subunit classifications of cultural preserve, natural preserve, and wilderness require different management strategies.

The use of prescription burning is recognized as an important resource management tool in a large number of California State Park System units. As a result, a fire management program has evolved over the past decade, and policy has been developed to guide this program.

Paper presented at the Wilderness Fire Symposium, Missoula, Mont., November 15-18, 1983.

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POLICY

Policies that guide the Department's burning programs have developed with the programs. In an earlier era, policies were defined to meet specific needs. Today a set of policies governs personnel involved in burning as well as the techniques.

Most of these policies do not differ greatly from those of other agencies, particularly with respect to safety, public notification, and planning. Our policies, particularly those involving techniques, strongly resemble those of the U.S. Department of the Interior, National Park Service, whose overall objectives and management philosophies more nearly approximate those of the California Department of Parks and Recreation.

Some of our policies are more conservative than those of other agencies. For example, we have a stronger need to balance esthetic considerations and the sensitivity of Park System visitors with the obvious needs of ecological objectives, fuel reduction, and fire protection.

Another important aspect of the Department's prescribed fire management policy is the recognition that adjacent residential areas are sensitive to our practices. Because many of our units are near large metropolitan areas and are in air pollution control districts, particular attention is paid to smoke management.

Because of the relatively small size of many units and adjacent residential developments, smaller burn compartments are used to avoid the overall appearance of burning a complete Park System unit. Smaller burn compartments also shorten the period of smoke disturbance over urban areas.

We must also consider the influence of certain interested parties. For example, one of the most successful acquisition programs for the California State Park System has been the Memorial Grove program of the Save-the-Redwoods League and the Sempervirens Fund. Taking a prospective donor to this fund to a recent burn site might jeopardize the donation if we have not been careful to educate the donor about the prescribed burn program. Thus, special policies guide us in this regard, and we are extra careful about scorch height, preservation of downed logs, and other visual aspects of the burned areas in these units.

We are particularly careful about training requirements for employees engaged in the prescribed burn program. (These requirements are the subject of a separate paper being presented at this Symposium by Peter Gaidula.) We require 2 weeks of classroom fire behavior and ecology training and 60 days of actual field burn training before a candidate can become a Level III Burner and be responsible for conducting a burn independently. Within the 60-day requirement a specific number of days' experience is required in three general vegetation types: grassland, brushland, and woodland or forest.

PROGRAM OBJECTIVES

The major objective of prescribed fire use in the California State Park System is to restore fire to its proper role in the natural ecosystems within the Park System units. In pursuing this objective we are mainly process, rather than object, oriented. That is, we are not so much concerned with how certain vegetation or wildlife are or are not affected or with reducing certain quantities of fuel as with allowing fire to perform its natural role, affecting the vegetation and site as it may.

Fire is not used as a management tool to favor any one plant or animal species as much as it is used to create a natural environment favorable to a balance of species that have evolved in that ecosystem complete with fire. This philosophy is the main guiding principle underlying our ongoing fire programs aimed at ecosystem management. It is the central focus of most of our burning programs.

There are, however, instances when we use fire to accomplish a specific manipulation of an ecosystem. For example, a new State Park System project in extreme northwestern California, the Lakes Earl and Tolowa project, is a wintering home for most of the world population of the Aleutian goose, an endangered species. Aleutian geese seem to prefer foraging on grazed pasture lands. We hope that a program of prescribed burning and grazing will enhance goose habitat.

Early photos of Marshall Gold Discovery State Historic Park clearly show the presence of an early successional stage forest on the backdrop of hills around the Historic Park area. A fire program in this unit will attempt to "freeze" the forest in a state resembling that which existed when the discovery of gold took place.

Finally, fire may be used as a treatment to restore or replace an ecosystem that has been altered or removed by factors other than the elimination of natural fires. This is particularly so in the control of exotic species. There are 44 plants identified as undesirable within the California State Park System. A number of these, we feel, can be controlled and perhaps eradicated through the use of fire in conjunction with other measures (table 1). Two examples illustrate such measures.

The first is the gorse eradication program at Jug Handle State Reserve on the Mendocino coastline of northern California. Gorse, a native of Scotland, forms an impenetrable head-high tangle of thorns that make an area entirely unusable. Its long-viable seeds make a continuing program of control necessary. Burning is useful to kill old-growth plants and to kill subsequent seedlings in later treatments.

Table 1.--Incidents of exotic plant species encroachment[1]

Region	Units and projects in region	Exotic plant species[2]											
		Thist	Broom	Eucal	Pampas	Icepl	Acaci	Tamar	Gorse	Tansy	Water	Other	Total[3]
Region 1	71	37	32	18	18	7	6	1	2	8	0	14	143
Region 2	82	35	34	43	42	35	20	0	6	0	0	40	255
Region 3	50	17	5	0	1	0	0	1	0	0	4	8	36
Region 4	97	26	0	7	1	4	2	7	0	0	0	31	78
State	300	115	71	68	62	46	28	9	8	8	4	93	512

[1]An incident is where one species in one unit or project is "a problem" or is not permitted by an approved unit resource management plan.

[2]The plant names are as follows: thistle, broom (French or Scotch), eucalyptus, ice plant, acacia, tamarisk, gorse, tansy ragwort, and water hyacinth.

[3]Forty-four different plants were reported under "other." Most common were water hemlock (13 incidents), castor bean (10), and periwinkle (8). Also included under "other" were native California species that had been planted outside of their natural range.

The second example, Angel Island State Park in San Francisco Bay, is an island slightly over 1 mi^2 (2.6 km^2) in size. It has been used as a military base from Civil War times until very recently. The island was heavily planted to eucalyptus at one time. The eucalyptus has taken over to the extent that it is now eliminating the beautiful views of the Golden Gate Bridge, Alcatraz Island, and the city of San Francisco. Burning here is complicated by the presence of historic wooden buildings. All of the eucalyptus groves have been burned at least once to stem the advance of the young trees. Large trees will have to be cut down manually, using fire to control the young growth.

PROGRAM DIRECTION

The California Department of Parks and Recreation began its programs in prescribed fire 10 years ago. Our emphasis during the first decade has been threefold.

The first major emphasis was to initiate a unit-wide pilot burning program at Calaveras Big Trees State Park. The purpose of this burning was to enhance natural germination and to protect the giant sequoia groves from wildfire, but it also demonstrated the importance and potential success of such a program to the public and those controlling potential funding sources.

Making Calaveras Big Trees State Park our fire choice for a unit-wide burn program was particularly significant. The giant sequoias, the Earth's largest living trees, are an irreplaceable resource. The program began in an effort to "fireproof" the magnificent South Grove, which is mostly undeveloped and remote. It is contained within the 1,200-acre (≅485-ha) Big Trees Creek watershed and is surrounded by forested private and federal lands. When burning first began in 1975, fuel hazards were enormous.

The Park was divided into over 50 compartments and each has been burned. Some of these burns eliminated large accumulations of downed fuels and duff. Some of the duff was as much as 23 inches (≅58 cm) in depth. The first cycle of burning was completed by 1981, and the grove became largely secure from potential catastrophic fire whether originating inside the grove or out. For the first time in decades there was substantial sequoia vegetation. We have nearly completed the first cycle of burning in the well-developed North Grove area and are continuing to reburn the South Grove, although fuel reduction efforts have not been substantial on any of the lands surrounding the Park.

Another of our goals was to train a cadre of burners in sound techniques and in the ecology of fire and fire effects. This goal was met during the early stages of the Calaveras program when we realized we needed to have our own people carry out our burns if we wanted to meet our management objectives. In addition, a larger number of trained burners would be needed if we were to expand the program to other units of the system.

A third goal was to monitor and measure the effects of prescribed fire through experimental burning in various ecosystems throughout the Park System. A distinctive aspect that sets our program apart from those of other agencies that are burning in California is our interest in and research on the effects of fire on the herbaceous elements within Park System units.

We began our prescribed burn program in 1973 on the coastal prairie at Montana de Oro State Park. We have continued it in a number of other grasslands at Point Mugu and Prairie Creek Redwoods State Parks, Sonoma Coast State Beach, Folsom Lake State Recreation Area, and Point Lobos and Jug Handle State Reserves. Some of these units with grassland have received numerous reburns, and data are being collected from permanent plots each year.

One example worth mentioning is the research at Point Lobos State Reserve. The Reserve's world-wide fame is primarily due to its claim to one of the world's greatest meetings of land and ocean. (It is located just downcoast from the Pebble Beach Golf Course on the Monterey Peninsula.) The native Monterey cypress groves and open meadows are also pleasing aspects of this State Reserve. Constant invasion by young pines into the Reserve's meadows could significantly reduce the superlative scenery of the area. Prescription burning has been employed to restore the meadows and to enhance the native components of the grasslands.

CONCLUSION

This year begins our second decade in the use of prescribed fire. Our programs have now grown and expanded to where over 40 units have had at least an initial reintroduction of fire by prescription burning.

A considerable amount of the annually budgeted money for resource management within the Park System is used for the prescribed fire program. A summary of the current year's expenditures is shown in table 2. A projection for the next 4 years is contained in table 3.

As our program continues to grow, we look forward to the eventual results of more natural and healthier ecosystems, greatly reduced wildfire hazards, and greater enjoyment by future visitors to the California State Park System.

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Table 2.--Prescribed fire management program for 1983-1984 fiscal year arranged by region

Region	Park system unit	Amount	Regional totals
		- - - Dollars - - -	
1	Angel Island State Park	2,000	
	Castle Crags State Park	4,000	
	Lakes Earl/Tolowa Project	2,000	
	Tomales Bay State Park	6,500	
	Annadel State Park	9,000	
	Salt Point State Park	6,750	
	Sinkyone Wilderness State Park	4,250	
	Jug Handle State Reserve	4,000	
	Prairie Creek Redwoods State Park	6,000	
			44,500
2.	Big Basin Redwoods State Park	28,210	
	Point Lobos State Reserve	4,300	
	Mount Diablo State Park	10,000	
	La Purisima Mission State Historic Park	5,000	
	Henry W. Coe State Park	19,300	
			66,810
3	Calaveras Big Trees State Park	88,312	
	Folsom Lake State Recreation Area	8,060	
			96,372
4	Cuyamaca Rancho State Park	65,000	
	Point Mugu State Park	10,000	
	Torrey Pines State Reserves	5,000	
			80,000
State	State-wide program	29,688	
			29,688
TOTAL			317,370

Note: Prescribed fire management funding is 66 percent of the available funding of $477,000 in the 1983-1984 Resource Management Program.

Table 3.--Unit-by-unit summary prescribed fire management program proposed, 1984-1985 through 1987-1988

Region	Park system unit	1984/85	1985/86	1986/87	1987/88
		- - - - - - - - Dollars	- - - -	- - - -	- - - -
1	McArthur-Burney Falls State Park	6,000	6,000	6,000	6,000
4	Topanga State Park	15,000	20,000	20,000	20,000
2	Montana de Oro State Park	9,000	9,000	7,000	7,000
4	Palomar Mountain State Park	11,000	11,000	11,000	11,000
4	Mt. San Jacinto State Park	10,000	25,000	20,000	20,000
3	Sugar Pine Point State Park	15,000	15,000	5,000	10,000
3	Caswell Memorial State Park	10,000	5,000	5,000	5,000
4	San Onofre State Beach	8,000	5,000	5,000	--
1	Humboldt Redwoods State Park	7,000	4,000	4,000	4,000
1	Austin Creek State Recreation Area	1,500	1,500	1,500	1,500
3	Malakoff Diggins SHP (Martin Ranch)	5,000	10,000	10,000	25,000
1	Trinidad State Beach	5,000	3,000	3,000	3,000
1	Jack London State Historic Park	11,000	8,000	8,000	8,000
1	Sugarloaf State Park	11,000	8,000	8,000	8,000
1	MacKerricher State Park	9,000	5,000	5,000	5,000
2	Andrew Molera State Park	5,000	5,000	--	--
2	Los Osos Oaks State Reserve	17,500	--	--	--
3	Malakoff Diggins SHP (Derbec)	--	--	8,000	8,000
2	Julia Pfeiffer Burns State Park	--	--	10,000	5,000
1	Mount Tamalpais State Park	--	--	--	10,000

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THE ROLE OF FIRE IN RESEARCH NATURAL AREAS

Janet Johnson

ABSTRACT: The role of fire in Research Natural Areas varies, reflecting the diversity of ecological conditions for which Research Natural Areas are established. For each Research Natural Area, assessment of fire's role requires (1) identification of the ecological conditions or features protected and (2) clearly stated management objectives. To achieve these objectives, fire management plans are needed; these should outline the use of prescribed unplanned and planned (Fischer's unscheduled and scheduled ignitions) ignitions and fire suppression techniques on a site-specific basis.

INTRODUCTION

Research Natural Areas (RNA's) are established to preserve a representative array of all significant natural ecosystems and their inherent processes (Federal Committee on Ecological Reserves 1977). The Federal system of Research Natural Areas initiated in 1927 includes almost 400 areas encompassing over 4 million acres (1½ million ha). As the network of RNA's expands in the current round of intensive land management planning, greater emphasis is being placed on the management needs of RNA's. This emphasis reflects the realization that designation alone does not guarantee preservation of the species, populations, or biotic communities protected within RNA's.

Concurrent with this focus on RNA management needs is a relatively recent shift in attitude and policy from fire control to fire management (Moore 1974; Kilgore 1976; Nelson 1979). This change is based on recognition of fire's importance as a major ecological process in many natural ecosystems (Habeck and Mutch 1973; Wright and Heinselman 1973; Kozlowski and Ahlgren 1974; Wright and Bailey 1980).

Because of the dual need to manage natural areas and fire in natural ecosystems, an evaluation of the role of fire in RNA's is timely. Although fire is one of the major ecological processes to consider in the management of most RNA's and is also one of the most significant natural disturbances that can be managed, the role of fire in RNA's remains controversial. In this paper I attempt to clarify and interpret the major issues, conflicts, and dilemmas regarding the role of fire in RNA's. Assessing fire's role in RNA's is a prerequisite to formulating RNA fire management policy.

RESEARCH NATURAL AREAS--DEFINITION AND PURPOSE

According to the Federal Committee on Ecological Reserves (1977):

> A Research Natural Area is a physical or biological unit in which current natural conditions are maintained insofar as possible. These conditions are ordinarily achieved by allowing natural physical and biological processes to prevail without human intervention. However, under unusual circumstances, deliberate manipulation may be utilized to maintain the unique feature that the Research Natural Area was established to protect.
>
> There are two primary purposes for developing a comprehensive representative system of Research Natural Areas:
>
> 1. To preserve a representative array of all significant natural ecosystems and their inherent processes as baseline areas. This action provides a potential range of diversity, including common, rare, and endangered species or disjunct populations.
>
> 2. To obtain through scientific education and research, information about natural system components, inherent processes and comparisons with representative manipulated systems. (Federal Committee on Ecological Reserves 1977)

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Research Natural Area is a designation specific to areas under Federal administration and ownership. Each RNA is administered by one of eight cooperating agencies: Forest Service in the Department of Agriculture; Bureau of Indian Affairs, Bureau of Land Management, Fish and wildfire Service, and National Park Service in the Department of Interior; Air Force in the Department of Defense, Department of Energy; and the Tennessee Valley Authority (Federal Committee on Ecological Reserves 1977). All involved agencies have similar regulations to ensure protection of their RNA's (Franklin and others 1972). Program execution and land management remain under the jurisdiction of each agency. A number of State agencies and private organizations (State Heritage programs, The Nature Conservancy, Society of American Foresters) are also involved in the process of identifying, establishing, and managing natural areas for similar objectives.

The general term "natural areas," which is also used throughout this paper, denotes land managed for preservation of natural ecosystems. This term includes wilderness areas, national parks, RNA's and other nature preserves.

PHILOSOPHIC DILEMMAS

Determining the role of fire in RNA's is complicated by two assumptions underlying the definition and purpose of RNA's.

1. RNA's are intended to preserve natural <u>conditions</u> and natural <u>processes</u>. These goals may not always be mutually compatible. Would fire, as a natural physical and biological process, always function to maintain the current natural conditions for which RNA's were established to protect? Isn't it conceivable that in some RNA's, fire burning under certain fuel and weather conditions could destroy the features for which the RNA was established?

2. RNA's include representative "natural" communities unmodified by human influence. Are RNA's truly free from human influence? If not, can fire be considered a natural process unless it is operating in a natural system?

The ensuing philosophic discussion pertains not only to the role of fire in RNA's but to other natural areas as well. Many of these issues were first recognized in the evaluation of vegetation management objectives for national parks and wilderness areas (Stone 1965; Boardman 1967; Houston 1971; Owen 1972; Parsons 1977; Stottlemeyer 1981; Bonnicksen and Stone 1982; Kilgore 1983).

Conflicting Objectives

The two major objectives of vegetation management are inherently contradictory. <u>Structural maintenance objectives</u> are designed to maintain, indefinitely, some desired structural or compositional state of vegetation. On the other hand, <u>process maintenance objectives</u> are intended to allow natural processes to predominate (Bonnicksen and Stone 1982).

<u>Structural maintenance objectives</u>.--For years natural ecosystems were seen as self-maintaining units that needed only protection from human influence to remain as they were (White and Bratton 1980. This traditional approach to preserving natural areas has usually meant protecting existing resources as if they were inanimate objects (Stone 1965; Lyon 1967; Parsons 1977). Vegetation preservation as a static concept is evidenced by phrases that define RNA's, such as "<u>maintaining</u> current conditions," "<u>protecting</u> some natural features," and "<u>preserving</u> a representative array."

Ecosystems are, however, structurally and compositionally dynamic. Plant communities can be altered by any number of natural disturbances, from those that can be managed--fire, erosion, deposition, and flooding--to those that cannot--windstorms, ice storms, frost-heaving, and species senescence (White and Bratton 1980). Furthermore, natural ecosystems include many disturbance-dependent species and communities. Attempting to maintain these dynamic biological complexes in any fixed condition is not only futile (Owen 1972) but introduces an element of artificiality contrary to the natural functioning of ecosystems.

<u>Process maintenance objectives</u>.--The current trend in vegetation management recognizes that allowing natural processes to operate in natural ecosystems is more likely to produce natural conditions than is vegetation management based on structural maintenance objectives (Houston 1971; Stottlemeyer 1981; Bonnicksen and Stone 1982). This is the generally accepted policy for vegetation management in national parks and wilderness areas (Kushlan 1979; Bonnicksen and Stone 1982). Conceptually, this is also the preferred management direction for RNA's.

Total reliance on intrinsic vegetation dynamics, however, requires a functionally insular ecosystem in which the driving biological and physical processes are generally endogenous. Even the largest natural areas (national parks and wilderness areas) are not completely self-contained, self-regulated ecosystems (Houston 1971). Although it is philosophically attractive to postulate that natural areas can be self-managing, there are few, if any, areas for which some form of human management is not a necessity (Lyon 1967; White and Bratton 1980). The resulting dilemma is that any management effort extends human influence into a natural world that preservation seeks ideally to keep free of human influence.

Human Influence

There is ample evidence that human influence, planned or not, direct or subtle, is unavoidable today, even in fairly large, remote wilderness areas. An ecosystem totally uninfluenced by human civilization exists only as a concept. Simply designating artificial boundaries may lead to ecosystem degeneration (Houston 1971; Kushlan 1979).

> When a reserve becomes isolated, it is doomed to change because of the loss of processes outside its boundaries that were necessary for its maintenance. The smaller the reserve, the further and faster it will change. (Diamond 1981)

These changes may include species extinction, decline of large native predators, imbalance of animal populations, and modification of migration routes. Modifications in vegetation structure and composition often result, and disturbances originating outside reserve boundaries are lost. This is exemplified by changes in natural fire frequency through loss of ignitions outside natural area perimeters. The origins of some impacts lie beyond reserve boundaries and may be more difficult to control than fire, such as exotic pests, diseases, plants and animals, air and water pollution, and modified hydrologic and climatic regimes (White and Bratton 1980).

Active ecological management is often necessary to neutralize or compensate for the unnatural human influences (Houston 1971; Owen 1972). In many instances, the need for active management is a direct result of former preservation policies that have failed to understand that ecosystems are dynamic.

Two paradoxes are present: (1) the goal of preservation is to preserve systems that must change and (2) managing for preservation introduces human influence into natural systems even when management's sole purpose is to correct or prevent human-related damage. Natural area managers must be either reconciled to human-caused and natural change or attempt to correct, guide, or prevent change (White and Bratton 1980). Neither management approach--preservation of specific vegetation conditions or preservation of natural processes--guarantees the primary objective, which is to maintain a natural situation free from human intervention.

RNA MANAGEMENT OBJECTIVES

In a discussion of management objectives for national parks, Owen (1972) expressed a desire for a general vegetation management goal that would apply to most national parks. If there is such a goal for Research Natural Areas, it is best stated by the Federal Committee on Ecological Reserves (1977):

> The goal of management is to maintain in as near a natural state as possible the ecological conditions for which the Area was designated.

The Federal Committee on Ecological Reserves has provided a number of general guidelines aimed at achieving this goal. These general standards for RNA management allow considerable discretion in determining management objectives and policies for individual RNA's and provide the flexibility needed to manage RNA's given the range of natural diversity encompassed within them, as well as the variation in RNA size, scope, and location.

Some RNA's because of their size, relatively undisturbed state, and remoteness approach a state of naturalness. The foremost management need of these large, essentially self-maintained RNA's is continued protection from any influence that could alter or disrupt ecological or geological processes. According to the Federal Committee on Ecological Reserves (1977), catastrophic natural events, such as insect infestations, fire, and climatological phenomena, should ideally be allowed to take their course. For these RNA's preservation of natural conditions based on process maintenance objectives is the preferred management direction.

Where environmental conditions within or surrounding RNA's have been altered, the best management strategy may be to simulate, rather than restore, natural processes. For these RNA's active management is necessary. The Federal Committee on Ecological Reserves (1977) states that although active management involving manipulative practices is not ordinarily permitted, there are a number of noteworthy exceptions. With regard to fire, prescribed burning may be used to maintain desired successional stages or to restore an area to the ecological conditions that existed before long periods of fire protection.[1] There is growing acceptance of prescribed fire in natural areas and reserves to meet ecological objectives where total reliance on natural fire is impractical (Good 1981; Ingles 1982; Kilgore 1983; Fischer in preparation).

For some RNA's the most appropriate management strategy relies on structural maintenance objectives. These sites include RNA's established to protect sensitive, rare, endangered, and threatened plant species and habitats. Other unique features include remnant stands of old-growth forests, unusual assemblages of plants or animals, or disjunct communities (Lyon 1967; Cain 1968; White and Bratton 1980; Good 1981; Matia 1983). For these RNA's, preserving specific vegetational conditions or communities takes precedence over preserving fire as a natural process.

The guidelines provided by the Federal Committee on Ecological Reserves, however, state that management practices should be founded on firm research using proven techniques that sustain predictable results. The general consensus of reserve managers is that the biological environment should be actively managed as seldom as possible (Owen 1972; White and Bratton 1980).

DEVELOPING A SOUND FIRE POLICY FOR RNA's

An evaluation of fire's role in RNA's must precede the development of fire management policies and plans for RNA's. This evaluation is based on the goal of RNA management--to maintain the ecological conditions for which the area was designated in

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[1] Editors' note: please refer to the Foreword for comments on prescribed fire terminology.

as near a natural state as possible. Selecting vegetation management objectives most appropriate to attain this goal will reflect the site-specific features within each RNA. Therefore, corresponding fire policy will vary from allowing fire to assume as natural a role as possible to total fire suppression.

The current Forest Service fire management policy is to recognize only two types of fire--wildfire and prescribed fire. Fires not under prescription require immediate suppression. It is for this reason that determining fire management policies and plans is one of the foremost management needs for RNA's

Fire management is the deliberate response to and use of fire based on technically sound plans that contain specific prescriptions intended to achieve stated management objectives (Fischer in preparation). Before natural fire (unplanned [unscheduled] ignition) is allowed to burn in an RNA, the area must be included within an approved forest plan or fire management area plan. The fire must meet specific prescribed conditions and management objectives. Prescribed burns from planned (scheduled) ignitions must also have approved fire management area plans.

The presence or absence of fire and fire frequency are of major significance to the natural functioning of fire-adapted ecosystems. Although many of the dilemmas and controversies regarding the role of fire in RNA's are philosophical, the problems that result from lack of firm guidelines and management policies are not so academic. These issues should be faced rather than avoided as the RNA system expands and the need for management increases.

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COMMENTS ON THE ROLE OF FIRE IN RESEARCH NATURAL AREAS

Charles A. Wellner

ABSTRACT: Statements by the Federal Committee on Ecological Reserves, personal involvement of over 50 years in Research Natural Areas, and the increasing rarity of undisturbed and climax stage vegetation lead to the conclusion that fire, and other disturbance practices, should seldom be used in Research Natural Areas. If used, they should be used only where essential to maintain the conditions the Research Natural Area was established to protect.

First, let us define Research Natural Areas (RNA's) and consider some of the problems we face in their management. In the 1977 publication, "A directory of Research Natural Areas on Federal lands of the United States of America" (USDA Forest Service 1977), the Federal Committee on Ecological Reserves has defined Research Natural Areas as follows:

> A Research Natural Area is a physical or biological unit in which current natural conditions are maintained insofar as possible. These conditions are ordinarily achieved by allowing natural physical and biological processes to prevail without human intervention. However, under unusual circumstances, deliberate manipulation may be utilized to maintain the unique feature that the Research Natural Area was established to protect.

The committee stated that

> From the inception of the program there have been two primary purposes for developing a comprehensive and representative system of Research Natural Areas:
>
> 1. To preserve a representative array of all significant natural ecosystems and their inherent processes as baseline areas. This action provides a potential range of diversity, including common, rare, and endangered species or disjunct populations.
>
> 2. To obtain, through scientific education and research, information about natural system components, inherent processes, and comparisons with representative manipulated systems.

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The committee expressed the need for Research Natural Areas for science and education, baseline studies, and germ plasm reservoirs. The committee also suggested principles of protection. In the section on management practices, the committee stated:

> The goal of management is to maintain in as near a "natural" state as possible the ecological conditions for which the Area was designated. Activities cannot be permitted that directly or indirectly modify the natural biota or the processes governing its intended composition. Likewise, permanent structures should not be permitted within the confines of the Area and only minimal temporary or semi-permanent research installations should be approved. The guidelines below provides some of the essential management standards. Generally management practices should be founded on firm research so that predictable results are sustained. Manipulative practices and research will not ordinarily be permitted. However, to achieve several anticipated objectives some exemplary exceptions are listed. Maintenance of otherwise transient stages in the vegetation succession may be desired in some Areas and will require management. For areas that are sufficiently large, a portion should be retained in the unmanaged condition. Only proven techniques founded upon experimentation at other sites should be utilized. Management may be achieved through such measures as prescribed fire to simulate wildfire, use of firearms, or reintroduction of predators to control excessive populations. Restoration should be initiated on an Area that is no longer valued for its established purpose and if the effort is judge feasible. Manipulation may be required to restore an Area to those ecological conditions which existed prior to disturbance. For example, after a long period of fire protection, it may be desirable to reduce litter accumulation by carefully controlled combustion so that a fire-adapted vegetation can better survive wildfires. Lands which are deemed infeasible or inadequately restored should be replaced with an area that fulfills the initial objectives of the Area.

Those committee members who wrote the "Standards and policy guidelines for Research Natural Areas" had a good understanding of the problems encountered in protecting and managing such areas, but the guidelines leave much to the discretion of those who must decide on appropriate protection and management practices for each RNA and to the managers who must live with prescribed practices. Using the statements of the Federal Committee as background and my own experience of 50 years with RNA's, I would like to make several observations regarding the extent to which natural processes involving fire and other perturbations should be allowed to operate in RNA's.

1. As the goal of RNA's is to maintain as near-natural conditions as possible, natural processes should be allowed to operate to the extent feasible.

2. The overriding consideration is to maintain conditions that each RNA was established to protect. Protection and management practices must be tailored to the conditions and features that each area was designed to preserve. It is important, therefore, to clearly state in the establishment document the major feature or features of the RNA.

3. Protection and management practices must be specified for each RNA. I believe that the best place to state these practices is in the document that establishes the RNA.

4. The Federal Committee stated "Manipulative practices and research will not ordinarily be permitted." This means that manipulative practices should be used only in unusual situations to maintain the condition the RNA was established to protect. Most RNA's in the Western United States are established to preserve an undisturbed habitat type or types. Usually it is not necessary to preserve a particular stage in succession, hence the use of fire or other disturbances is not needed. Certain RNA's, however, are established to preserve a seral stage in succession or species that require a seral stage for survival. These circumstances normally require manipulation to maintain the seral condition.

5. The committee said also that "Only proven techniques founded upon experimentation at other sites should be utilized." The point is that only proven practices that will provide known results should be used. If there is uncertainty regarding results, the practice should not be used. RNA's are not the place to experiment with manipulative practices.

6. The committee said little about wildfire except the following: "Catastrophic natural events, such as insect infestations, fire, and climatological phenomena, should be allowed to take their course. However, as a practical matter... such a policy may be impractical." It seems to me that wildfire should seldom be allowed to burn in RNA's. If fire is needed to maintain certain conditions, prescribed fire should be used where its use can be certain and controlled. Control of wildfires in RNA's should be accomplished with a minimum of disturbance. In general, hand tools and hand methods are preferred to heavy equipment. In prescribed burning, all disturbance except that resulting from the fire should be minimized.

7. Other catastrophic natural events in RNA's presents problems, too. Little can be done about climatological events and ordinarily no attempt should be made to clean up or modify conditions after the event. Insect infestations should be allowed to run their course unless doing so endangers surrounding resources. Although in some instances insect control actions may be necessary, it is important to consider how successful and certain most insect control measures are. Unless results are predictable and certain, control should not be undertaken.

8 What should be done about nonnative introduced pests in RNA's such as white pine blister rust, the larch casebearer, and the balsam woolly aphid? Again, probably nothing because control methods are either not available or not practical in RNA's.

9. Undisturbed conditions are already so rare, or fast becoming so rare, that they urgently need protection. Every square foot of the earth's surface has been affected to some extent by human influence. The effects may be caused by a slight modification of sunlight and surface temperatures produced by contrails of airplanes, by pollutants that affect animal and plant life, or by livestock grazing which may have minimal or drastic effects on plant life and soils. We cannot hope to preserve pristine conditions because they no longer exist; however, we can preserve the best we have left and protect reserved areas from further disturbance to the best or our ability. Because the undisturbed condition is rare or is fast becoming so, we should not use practices that cause further disturbance in RNA's except where needed.

10. Even more rare is vegetation in an undisturbed advanced stage of ecological development. Disturbance resulting from many protection and management practices creates seral conditions; in fact, much of our management is aimed at creating seral conditions in order to perpetuate valuable plant resources. Yet over much of the Western Untied States the ecological classification system that we use in management--habitat types--depends on a knowledge and understanding of the climax stage of succession. It is the end stage of succession that is fast becoming rare. If we protect RNA's from disturbance, they can provide good and valuable examples of climax conditions for reference and study. It seems important, therefore, to use disturbance practices, including fire, in RNA's only when needed to preserve seral conditions.

11. Finally, a reiteration: Use fire only where essential to maintain the conditions the RNA was established to protect. And when in doubt about the use of fire or any other practice in RNA's, do nothing!

245 FIRE POLICIES AND PROGRAMS OF THE NATIONAL PARK SYSTEM

David B. Butts

ABSTRACT: The fire management program of the U.S. Department of the Interior, National Park Service, has experienced increasingly rapid change over the past two decades. The innovation of the 1970's is evolving into the professionalization of fire management during the 1980's. The segmentation of wildfire suppression from prescribed fire is giving way to a comprehensive approach of dealing with fire management as a whole. The ultimate objective, which has been attained in some areas already, is park fire management programs that are commensurate to the needs of park resources and in line with national policy.

INTRODUCTION

The comprehensive fire management policies and programs of the U.S. Department of the Interior, National Park System, are the product of more than two decades of evolution. Before that time, fire programs in the parks were based on suppression only. No one considered the contributions fires of natural origin may have made to the natural systems of the parks.

Today's comprehensive approach began with concepts expressed in the Leopold report (Leopold and others 1963) and that were first formally stated in the U.S. Department of the Interior's administrative policies (1968). This approach recognized fires of natural origin as "natural phenomena" and also accepted prescribed burning as a means of achieving resource objectives.

The 1970's are best characterized as a period of innovation. Policy provided a broad conceptual guide for fire programs; managers and fire personnel had little guidance and few constraints. The result was a wide array of programs. Each program relied upon individual fire staff to develop the criteria and the processes by which programs would be managed. This innovation fostered many concepts that have merged and crystallized in the 1970's. These concepts are evident in revisions of sections on fire in the management policies of 1975 and 1978 (U.S. Department of the Interior 1975, 1978a). Their influence is also evident in the detail ultimately developed in the Fire Management Guidelines, NPS-18 (U.S. Department of the Interior 1978).

In the 1980's fire management is evolving into a mature and responsive program throughout the entire National Park System. A basic premise of this phase is that professionals within the parks will be trained to run the fire programs and will be trained to a level commensurate to parks' needs. Our normal fire year programming (FIREPRO) is designed to provide that minimum level of decision capability.

FIRE POLICIES: A REFERENCE POINT FOR MANAGEMENT

In the National Park System, we manage natural areas and designated wilderness areas in the same manner. The resource concepts expressed throughout the management policies apply equally to portions of parks inside and outside of the congressionally designated wilderness (U.S. Department of the Interior 1983). For the sake of simplicity, my references to parks in this discussion apply also to those natural areas and designated wildernesses within parks.

Policy Evaluation

In 1968 the thrust was to awaken an otherwise methodical fire suppression program to the realities of natural area and wilderness needs. The administrative policies for natural areas were extremely terse in regard to fires and reflected the reaction to total suppression expressed in the Leopold report (U.S. Department of the Interior 1968). The early research in Everglades National Park under Dr. Robertson and in Sequoia and Kings Canyon National Parks under Dr. Hartesveldt documented the need for change (Robertson 1953; Hartesveldt 1964). It characterized fire as a natural phenomenon. It did not necessarily refute today's concept of fire management, but neither did it define how the concept of fire as a natural phenomenon should affect the management of individual parks.

The policy that developed was in keeping with Service-wide management philosophy at that time and permitted wide innovation. Many of the formally structured handbooks of the National Park System were set aside during that period, and managers were given opportunities to also adopt new programs for many other aspects of park management.

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This shift also fostered an increase in questioning by fire managers and researchers who were trying to tie together the opportunities provided by the policy, the diverse resources and objectives in parks, and the National Park System. In the early 1970's, policy was almost void of specific guidance regarding fire programs. Innovation took place in isolated parks and depended upon individuals, their training, expertise, and motivation. This fragmentation fostered both total inaction and exceptional accomplishments in parks.

In the early 1970's, the motivation and enthusiasm of some individuals eventually led to meetings of park and forest personnel who wanted an opportunity to exchange information and to seek answers and reinforcements for the isolated programs. It was recognized that there was a need for fire to be addressed appropriately in all parks in the System. This included not only the broad natural or wilderness areas of the National Park System but also the more numerous small and culturally based parks that make up the 334 units of the National Park System. These irregular aggregations of 20 to 30 fire staff members from the United States and Canada fostered and spread the basic concepts from which today's policy evolved.

In 1975 we completely rewrote our policies, from the standpoint of park management as well as fire management (U.S. Department of the Interior 1975). The phrase "management fires" was coined to characterize the contribution of prescribed burns[1] and prescribed natural fires to park management. The phrase was understandable to the public but was dropped in the 1983 version in favor of the broad definition of prescribed fire as used by fire professionals. "Prescribed fire" is a contrast to "wildfires."

The most significant portion of the 1978 revision was that which specifically tied policy to park objectives. This change became necessary when the natural, cultural, and recreational management categories to which the earlier administrative policies had been tied were eliminated. In fire management especially, the broad concept of fire as a natural phenomena was put in the context of its appropriateness or inappropriateness, depending upon the blend of national policy and park management objectives.

The policy was expanded upon in Fire Management Guidelines, NPS-18 (U.S. Department of the Interior 1978), which were the first complete instructions for park fire programs. They instructed superintendents to build a program commensurate to the needs of the park and provided a detailed policy that was to give all levels of management a consistent point of reference for fire management.

[1]Editor's note: Please refer to the Foreword for comments on prescribed fire terminology.

The greatest change in the latest revision (1983) is the return to a classic sequence (prevention and suppression) followed by prescribed fire. A brief glossary was also included in an effort to eliminate confusion (U.S. Department of the Interior 1983).

As pointed out by Dickenson earlier in this symposium, this policy spans a diverse National Park System and must therefore be coupled with much more specific objectives for each park if we are to truly perceive the proper role of fire management. Unfortunately, in settings such as this symposium it is much more difficult to generalize about fire management applications. Fire management policy is best understood in reference to a specific park, where both the objectives for the park and specific parcels of land involved are known in addition to the policies themselves. The management zones within the parks include natural and wilderness zones. In addition, there are development zones and special use zones that may have significantly different fire management objectives. We are focusing here on the application of fire management to the natural and wilderness zones of the park, which are comparable to the designated wilderness of the National Forest System and the other agencies.

Implications For Unit Diversity

The numerous units of the National Park System are diverse in size as well as vegetation. The physical area also influences the viable options available to park managers within fire management policy. Extensive areas such as Yellowstone National Park and the parks in Alaska provide a much wider range of management options than would be found in a small restricted natural park such as Muir Woods National Monument. Between these extremes, we find most of the areas of the National Park System. Whatever option is chosen, changing technology forces managers to continuously reassess the extent to which their programs can be adapted to achieve the optimum results described in the management policies.

Implications For Wildfire Management

Managers must also maintain an appropriate prevention and suppression capability to respond to wildfires in the National Park System. The suppression program is necessary to prevent unacceptable modification of these extensive natural systems by modern society. There is a major threat to these portions of parks by the ever-increasing number of visitors--almost 250 million in 1982. This requires a continuing awareness by management to avoid the impact of human-caused wildfires.

Suppression programs are designed to minimize the size of wildfires and their impacts. Although the Service now uses the least damaging suppression technique, we still unfortunately have examples of disturbance associated with suppression action on

old wildfires. This disturbance is more visible today, several decades after the fire, than is the impact of the wildfire itself. High-impact suppression techniques are no longer acceptable.

Implications For Native American-ignited Fires

Management policies do not specifically refer to the role of fires ignited by Native Americans. This is not to say that we refute the influence of the aboriginal population of this country on the vegetative mosaic. We recognize that the visual impression of the parks may have been influenced by those fires. We must also acknowledge that many of the previous fires that burned the national parks were careless acts of more recent immigrants to the United States. Unfortunately, it is virtually impossile to differentiate among fires started by Native Americans, European settlers, or lightning. Even with thorough research, judgments regarding specific tracts of land are in large part subjective. We feel that the only feasible management solution to this situation is to acknowledge that humans played a role in influencing the vegetative mosaic and fuel loading of the country and to proceed with as technically sound a fire management program as possible using lightning- or volcanic-caused natural ignitions.

Implications For Prescribed Natural Fire

The policy regarding "prescribed natural fire" epitomizes our fire management in wilderness. Although many questions have been raised about the phrase, the concept persists. The Service develops prescriptions for various fire management units before natural ignitions--primarily from lightning--occur. This process allows the Service to carry out natural area management with a minimum investment in research and simultaneously avoid continued suppression impacts. It also provides the maximum opportunity to attain natural diversity and eliminates most of the arbitrary human decisions on these fires. Where parks are unable to use this technique because of extremely restricted geographic boundaries, prescribed burns can be substituted for prescribed natural fire within the specifically approved park plan. Those programs are continuously reviewed as state-of-the-art changes and further refinements permit more parks to attain their objective of natural systems management.

The policies of the National Park System are designed to establish an attainable management program based on reasonably valid criteria. In many cases, this is feasible without infinite research into the precise effects of fire on all species. It at least permits progress in the right direction. As time and resources permit, these programs can be refined to more precisely achieve the desired objectives.

This approach also permits limited research dollars to be directed to crucial common issues, such as exotic or endangered species, fire behavior, and meteorological research. Advances in these areas would permit us to further refine the prescriptions and their reliability.

For example, if lightning occurs within a park, there is obvious potential for the natural role of fire. No research is needed because the potential for lightning fires is obvious. Lack of research on the precise effect of all lightning fires need not preclude adopting a prescribed natural fire program. The park must define the constraints and opportunities in regard to such fires and revise their fire management plan accordingly.

PROGRAMS: POLICY IN REAL LIFE

The fire management program described here is intended to be all encompassing, covering the full range of options from prevention, presuppression, suppression, and the use of prescribed fire where it contributes toward park objectives. The capability to carry out such a program rests upon two essential components. Knowledgeable staff is the first and foremost of these. The staff must have adequate knowledge of fire behavior, the equipment associated with fire, and the relationship of fire to the resources of the park in order to guide the program toward the objectives. The second component is support by technology. In the past, the intuitive judgment of individuals was the major component of fire management; it was complemented by fire equipment. Today, supporting technology, particularly in the field of fire behavior and modeling, is rapidly increasing both in complexity and volume and plays a far more significant role. This places an additional burden on the staff to remain knowledgeable but also provides that staff with greatly expanded capability.

To keep in context the diversity found within the National Park System, we might examine the present array of parks being incorporated in FIREPRO. We adapted the normal fire year planning process of other agencies to the particular needs of the National Park System. Our version, FIREPRO, joins constrained operations analysis to the budget formulation process. It is operational in 16 parks, the regional and Washington offices. Our goal is to expand to include the full 202 parks with wildland fire occurrence.

Table 1 shows that most parks are relatively small and have limited fire management programs. Only eight parks are at Level III, at the upper end of the spectrum; they have highly complex programs, large geographic areas, and high fire occurrence and potential. Future program refinement and maturation will take place primarily in the large aggregation of less complex Level II parks. Most of these parks have full suppression programs and fairly modest fire occurrence. Many will need to reassess fire causes and influence and their fire management objectives and to revise their fire

management plans accordingly. The simplest programs are Level I, which have low occurrence and low potential. People managing these programs also get in trouble the fastest in exceptionally bad years due to their limited experience with fire.

Table 1.--Service-wide levels of emergency presuppression programs

Complexity levels	Number of parks
Level I	160
Level II	28
Level IIA	6
Level III	8
Total	202

The levels, from I to III, reflect an increase in complexity of emergency presuppression programs.

Wildfire

This symposium focuses on the management of natural systems and wilderness, so much of our emphasis is on the application of prescribed fire. Without the undergirding of an effective prevention and suppression program, however, the National Park Service will not be able to achieve the objectives for which these parks were set aside. The natural influence of fire on the system is meaningful only to the extent that those systems have not been upset by modern humans. To assure that human effects remain limited, a state of preparedness must be maintained with both personnel and equipment to combat wildfires.

Hundreds of thousands of people visit even remote portions of national parks, which are the primary emphasis of this symposium. National parks received overnight use of about 2.5 million camper days in 1982. The percentage of human-caused annual fire occurrence varies considerably among parks; however, the national average based on our FIREPRO analysis indicates that 63 percent are human caused. Our objective is to minimize, to the greatest extent possible, the influence of human-caused fires on the natural systems.

FIREPRO implementation in a park involves such technologies as the use of AFFIRMS and the TI-59 calculator to run fire behavior and planning models. The computer terminals many parks now have will play a greater role in future weather analysis and planning. The access to this type of information is basic to sophisticated management. The other equipment and supplies essential to execute these appropriate fire programs at the park are also defined by FIREPRO analysis. The number of slip-on water expansion units, engines, and fire cache contents, such as the basic shovels and flappers, completes the physical capability.

One major byproduct of FIREPRO is the assurance of decisionmaking capability in the park to guide the program based upon data from the normal fire year. Knowledgeable fire staff is the key to the suppression program as well as to subsequent refinements of prescribed fire that yield a comprehensive fire management program.

The fire arena can be expanded to include park neighbors through interagency agreements. In Yellowstone National Park such agreements are the key to mutual aid on wildfires. They also provide for prescribed natural fires to cross boundaries if such practices are mutually agreeable.

The suppression program, with its training, decision capability, data base, and equipment, is an integral facet of the management of the park ecosystems. It provides a sound technical basis for protection of park resources and a foundation upon which to build other prescribed fire applications.

Prescribed Fire

Those personnel that oversee the fire management program must have enough experience to know what fire does before they attempt to adapt it to specific objectives. The intelligent use of prescribed fire rests upon two tough management decisions. The first is whether prescribed fire is desirable and feasible. The second is determining where, when, and how prescribed fire can achieve the desired objectives.

We have the opportunity to use the computerized fire behavior modeling and analysis to assess park needs and design prescriptions. Wildfire occurrence and its behavior can also give us information needed to build or refine prescriptions.

Complex fire management programs carry with them additional obligations. Managers must support specific training programs to ensure that staff possess appropriate levels of knowledge and experience before prescribed fire plans are designed or carried out. An effort must be made to assure continuity of qualified staff because park and wilderness management entails the perpetual management and care of these areas through this and future generations.

Guidelines provide technical information necessary for prescribed burn programs and identify the best possible course of action for the park. Everyday management concerns often make it easy to ignore critical facets of burn plan execution, particularly in an impatient push for results. We have all seen this happen with prescribed fires. We must avoid initiating a burn just to get it over and must follow the carefully developed prescription even if it means canceling costly preparations. The proper results are paramount, not the schedule.

Our prescribed fire program has two broad categories--prescribed natural fire and prescribed burns. Prescribed natural fire is our primary

program in natural zones and wilderness. Any discussion of it requires an explanation of how we regard prescribed natural fire and why we feel it is our ultimate objective.

Prescribed natural fire.--The natural systems associated with the parks should determine the distribution, intensity, and timing of the fires. A lightning storm may produce a variety of lightning strikes. Which of these strikes begins fires and ultimately affects the vegetation is determined by an extremely complex aggregation of vegetative and atmospheric factors. We do not ever expect to obtain enough scientific data to enable us to exactly replicate that process. In the absence of that capability, planned management constraints, in the form of fire prescriptions, are the only feasible means to effectively manage natural fire effects. Where we have implemented such programs, we have determined those constraints that we must attempt to apply to natural fires. They include such parameters as the geographic limits to fire spread, the intensities we feel we can adequately manage and, obviously, such overriding considerations as the protection of human life and property. Such prescriptions may be much briefer than those for prescribed burns, but they are prescribed long before ignition occurs.

Our prescribed natural fire program permits us to end the arbitrary full suppression policy, for fires of natural origin, that previously applied to extensive park areas. As more is learned about the various effects of fire, we may be able to further expand the prescribed natural fire program into other areas of parks.

Prescribed burn program.--Our prescribed burn program, which includes all forms of deliberate ignition of prescribed fires, is much more detailed and much more restricted geographically. Only a dozen or so parks are involved. We permit prescribed burns within the natural areas and in designated wilderness, primarily to restore natural fuel loadings, but only under carefully constrained conditions and according to specific burn plans for a park or subunit.

We hope that using prescribed burns to restore natural fuel loading is a strategy we will be able to phase out. In a park that has a fuel load 50 percent above what would normally have occurred in the absence of past suppression, the objective of prescribed burns would be to reduce that fuel loading by 50 percent. If this were accomplished in a series of one or two prescribed burns over most of that area, that segment of the park could then be reclassified as a prescribed natural fire unit and further arbitrary prescribed burns would no longer be used.

A second use of prescribed burns is to reduce hazards along park boundaries where no agreements exist to allow prescribed natural fires to cross them. The reduced fuel zone helps protect adjacent private properties and also helps us prevent the spread of wildfires from surrounding areas into the natural system.

Another facet of hazard reduction is in and around developed areas within the parks. The presence of large volumes of fuel within developments makes it virtually impossible to effectively deal with fire hazard, let alone prescribed natural fires on adjacent wildlands. They could not be prevented from spreading to those developments and destroying them or endangering the occupants. Prescribed burning in and around developments to reduce the fuel accumulation may permit us to improve protection and to increase the size of the adjacent prescribed natural fire units.

Last, prescribed burns are used in limited areas to physically manipulate the park vegetation, particularly if we determine certain species are being lost due to the absence of fire and no other alternatives, such as prescribed natural fire programs, are feasible. Prescribed burns are also used in our cultural and recreational parks where we have purposes other than maintaining pure natural systems. In our cultural areas, we may manipulate the vegetative cover to perpetuate fire subclimax species, such as the pines in the southeastern United States or open fields on battlefield sites to mimic the historic setting.

In all cases of the prescribed fire program, we are fully capable of suppression action should any fire exceed its prescription. This includes reacting with forces on the ground as well as forgoing prescribed burns and, when extreme fire danger exists, rapidly suppressing what would otherwise be prescribed natural fires. These tactics are especially important when wildfire suppresion forces have already been overtaxed locally or nationally. In this sense, the prescribed fire program in the National Park System is considered as an opportunity for management refinement but only in the realistic context of the potential for wildfires.

All prescribed fires that exceed prescriptions are reclassified as wildfires and remain so classified until they are out. We categorize wildfire management according to levels of intensity: management that confines, contains, and controls in increasing order of aggressiveness. These criteria are also used by the U.S. Department of Agriculture, Forest Service; similar fire management programs are evolving in other federal land management agencies.

CONCLUSION

The past decade has been marked by rapid change (for a bureaucracy) in policy and programs; the intent has been to guide and support park fire programs. This effort was facilitated by tying park resource objectives to national policy and programs.

In "Megatrends," Naisbitt (1982) characterized the process when he said "the richness of the mix always results in creativity, experimentation, and change." Fire management over the past decade has been rich in the number of highly motivated individuals, agencies, and disciplines involved. The resulting changes have yielded quality programs.

FIREPRO will enable us to carry out our fire management program. It will assure continuing capacity for decisionmaking in the parks and will provide the personnel and equipment needed to execute the programs. The options available to the manager in each and every park with natural systems and wilderness will be adequate and realistic.

The goal of National Park System policies and the programs is comprehensive fire management--a totally integrated application of suppression and prescribed fires to attain park objectives. To use a cliche, a chain is only as strong as its weakest link. The National Park Service strives to assure that all links in this comprehensive program are adequate to assure implementation of quality fire management in the natural systems of the parks and their designated wilderness.

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FIRE MANAGEMENT POLICY AND PROGRAMS FOR NATIONAL FOREST WILDERNESS

Everett L. Towle

ABSTRACT: All wildfires on national forest lands are treated the same, whether within wilderness or outside wilderness. Suppression techniques are modified, however, by wilderness constraints. We have used prescribed fire from unplanned ignitions[1] (lightning) in some areas since 1972 with moderate success. Planned ignitions also have a place in wilderness management for meeting specific wilderness resource management objectives that cannot be met by unplanned ignitions alone.

INTRODUCTION

The U.S. Department of Agriculture, Forest Service recognizes only two types of fire, wildfire and prescribed fire. Often the public and public employees confuse them. It is important for all of us to be able to clearly distinguish between them in spite of their apparent similarities.

WILDFIRE POLICY

All wildfires, whether within wilderness or outside it, require immediate suppression. The consequences of not requiring immediate suppression sooner or later produce a devastating wildfire. The type of suppression response depends upon management objectives, resource values, safety considerations, and suppression costs for the particular area and situation. Suppression responses to meet management direction may range from direct control, which includes stopping the spread of wildfire and mopping up all hot spots; to containment, which involves limiting the spread of wildfire; to confinement, where a wildfire will be prevented from spreading because of the natural breaks and barriers that surround it.

Decisions about the initial response should be based on management objectives, projected suppression costs, land and resource values, potential resource losses, reinforcement capabilities, and significant economic, environmental, political, and social concerns; this evaluation will be affected by considerations of probable fire behavior and firefighter safety. If the initial response does not produce the expected outcome, the wildfire becomes an escaped fire. At this point, the forest officer responsible for wildfire organizes and implements additional suppression action based on an escaped fire analysis. The suppression alternatives developed in this analysis are the same factors previously mentioned. Appropriate actions will continue until the wildfire is suppressed.

Wildfire suppression actions in wilderness are designed to minimize human impacts upon wilderness, however, use of mechanized equipment can be authorized by the Regional Forester in major fire suppression emergencies where lives, private property, and adjacent resource values are threatened.

PRESCRIBED FIRE POLICY

Prescribed fires are used in U.S. Department of Agriculture, National Forest lands as a safe, carefully controlled, economical, and ecologically sound way of partially or totally eliminating fuel buildup to achieve specific objectives. They may originate from scheduled or unscheduled ignitions.

Planned And Unplanned Ignitions

With planned ignitions, the manager chooses location, timing, intensity, and size for each fire. Such burns are initiated when all fire behavior components (above) indicate that a planned burn will accomplish the objectives listed in the prescription and that the fire will remain within prescription.

Unplanned ignitions are naturally occurring or human-caused. The former are caused by lightning. The latter are fires that management cannot control with respect to timing and location but that nevertheless meet predetermined objectives, and will (according to forecasts) stay within prescription.

When an authorized forest officer determines that an unplanned ignition meets planned and approved prescription criteria for an area, the fire may be designated and managed as a prescribed fire. Before this can be determined, however, the following four conditions must be met:

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[1] Editors' note: please refer to the Foreword for comments on prescribed fire terminology.

1. The Regonal Forester must have approved a Forest plan or a fire management area plan that includes unplanned ignitions.

2. Weather forecast projections must indicate all existing and predicted fire behavior parameters will remain within the permissible range established in prescription for the short-term; in addition, all long-range trends must look favorable.

3. Project funds must be available for surveillance and monitoring.

4. A sufficient contingency force must be available in the event the fire must be suppressed.

If any of these conditions is absent, the fire will be immediately treated as a wildfire, and appropriate suppression action will be taken.

PRESCRIBED FIRE POLICY IN WILDERNESS

Since 1978, and even earlier in some areas (White Cap Study Area, Selway Bitterroot Wilderness 1972), prescribed fires originating from unplanned ignitions, mainly lightning, have been permitted to play a more natural role in the ecology of designated wilderness areas. Up to now, we have not provided for planned prescribed fires in wilderness. The Chief of the Forest Service, however, has always had the authority to consider, on a case-by-case basis, proposals for using prescribed fire from planned ignitions in special circumstances. The 23,422-acre (9 474-ha) Bradwell Bay Wilderness in the Apalachicola National Forest in Florida may be the first such proposal submitted to the Chief for using planned ignitions within wilderness; however, Forest Service Region 8 has not completed their package as of this date. The Bradwell Bay Wilderness, which is surrounded by high-value timber and developed areas, was previously maintained by prescribed fire from planned ignitions before its designation as wilderness on January 3, 1975. Without the use of planned ignitions, forest fuels will continue to accumulate to the point that a wildfire in this wilderness area will seriously threaten all the resources adjacent to the wilderness boundary.

Although we have discussed the use of planned ignitions to meet specific wilderness management objectives periodically, before using planned ignitions, we wanted to determine what could be accomplished with unplanned ignitions. We now know that we cannot depend totally upon natural sources of ignition because of problems with location, frequency, timing, adverse air quality impacts, risk, and loss. Many wilderness areas simply do not have the natural fire frequency needed to reverse the conditions resulting from numerous years of fire suppression.

Air quality impacts may place an even more serious limitation on the use of unplanned ignitions in some wilderness areas. Planned ignitions may avoid this problem if they are designed to burn for 1 or 2 days during periods of good vertical mixing and high-elevation transport winds.

The Chief is considering delegating the authority to approve planned ignitions in wilderness areas to each Regional Forester. Whoever makes this decision, however, must consider planned ignitions in the context of the forest plan or a separate in-depth analysis. In addition, planning and public involvement must be followed by monitoring and post-burn evaluation; the factual data gathered should support the use of planned ignitions. Although we can do a good job in this area, we will need continued support from research, particularly in the area of postburn evaluations.

We must clarify our objectives. Restoring the role of fire is a reasonable goal but not an acceptable objective. We must be sure that our use of fire is based on past fire history, and on the legislative intent for each individual wilderness and that its use supports one or more wilderness resource objectives.

We have the skills and technology to use planned ignitions in wilderness, but a good case must first be made for their use in meeting specific wilderness management objectives. Fire is almost the only available tool for perpetuating a desired ecological process and also maintaining the high-quality wilderness and resource values we enjoy today.

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A USER-ORIENTED VIEW OF FOREST SERVICE WILDERNESS FIRE POLICY AND PROGRAMS

Arnold W. Bolle

ABSTRACT: The Wilderness Society (TWS) is the first national conservation organization to adopt a policy statement on wilderness management. It states that

> The purposes of the Society shall be: To secure the preservation of the American wilderness wherever found and for this purpose to make or to initiate or cause to be made scientific studies and investigations concerning wilderness areas, their values and uses to the public, and the best methods for protection preservation, and use in the public interest . . . .

Although TWS recognizes the fact that fire is a natural force that should be permitted to play its ecological role in wilderness ecosystems, TWS feels that we should use caution with the use of fire in wilderness. The use of fire should be carefully planned with full public involvement.

INTRODUCTION

One year ago The Wilderness Society (TWS) became the first national organization to adopt a policy statement on wilderness management. Others are now following our lead. For the almost 50 years of its existence TWS operated under the broad policies of its bylaws, which said:

> The purposes of the Society shall be: To secure the preservation of the American wilderness wherever found and for this purpose to make or to initiate or cause to be made scientific studies and investigations concerning wilderness areas, their values and uses to the public, and the best methods for protection preservation, and use in the public interest . . . .

The Wilderness Act of 1964 carried the concept further when it said:

> A wilderness, in contrast with those areas where man and his own works dominate the landscape, is . . . recognized as an area where the earth and its community of life are untrammeled by man, where man himself is a visitor who does not remain.

Wilderness areas, according to the act,

> shall be administered for the use and enjoyment of the American people in such a manner as will leave them unimpaired for future use and enjoyment as wilderness, so as to provide for the protection of those areas [and] the preservation of their wilderness character.

In other words, the Act directs the managing agencies to maintain the processes of nature essentially uninterrupted, with man as an observer who does not interfere with, and certainly does not degrade, the wilderness resources.

In our policy statement, the guiding principle most apropos to the deliberations of this symposium is our first one:

> The purpose of wilderness management should be the maintenance, and, if need be, the restoration of a dynamic equilibrium of natural forces. Nondegradation of and noninterference with natural processes are fundamental. The goal is free play of natural forces, not any particular static condition. For example, the Wilderness Society generally supports a policy of allowing natural fires to play their ecological role in wilderness, with due regard for public health, safety, and welfare in the surrounding nonwilderness areas. (In addition, careful experimental burning may be considered to restore the natural equilibrium in fire-dependent ecosystems where decades of fire exclusion by man has led to unnatural conditions.) [emphasis added]

A guarded statement, yes. But a position that is well in line with the present state of scientific knowledge and technology.

I want to emphasize three points in regard to our policy statement. The first is the need for caution in the use of fire in wilderness; the second is consideration of what a "natural forest" is; and the third is the need to involve the public in the management process.

Paper presented at the Wilderness Fire Symposium, Missoula, Mont., November 15-18, 1983.

Arnold W. Bolle, Vice President and Chairman, Policy Committee, The Wilderness Society.

NEED FOR CAUTION IN USE OF FIRE

The fact that decades of fire control have led to unnatural conditions can no longer be disputed. There are places where this may be desirable, but in wilderness areas it is not. There we need to restore fire to its natural ecological position.

But we need to be careful. Prescribed fire is an important management tool; however, our experience with forest management tools has not been all that successful, and bad experiences could reduce our freedom to use this tool. We need to be especially careful with scheduled ignition (prescribed fire). Authority to use it in wilderness now resides only with the Chief of the Forest Service, although that authority may soon be delegated to the Regional Foresters. I have great confidence in the judgment of Regional Foresters; however, the authority needs to be used with considerable caution.

In our policy we advocate that scheduled ignition be used carefully and experimentally. Our concern is that its use be carefully considered and controlled and that its users have a definite purpose in mind. The results of its use should be measured and the knowledge gained accumulated and applied to further experiments. We do not believe that the present state of knowledge is sufficient for widespread application, and we fear that such use could lead to disaster that could restrict further use of this tool.

All areas need not be restored quickly. We are in a position that permits proceeding in a logical manner: We can first acquire information and then experiment with it to advance knowledge. We should then use and monitor this knowledge carefully and build the soundest possible program based on it. We should then be eager to acquire and use more prescribed fire in new situations. We need not rush forward with a program based on untested assumptions as has so often been done in other resource areas. Proceeding on the basis of untested assumptions often creates an amazing situation where knowledge is often rejected because it questions those assumptions.

DEFINING "NATURAL FOREST"

My second point concerns the definition of a natural forest, which is essential in defining our wilderness management goals. In our policy statement our third principle says that

> <u>Necessary management actions should be based on clearly defined objectives that describe desired wilderness conditions and are set forth in individual management plans prepared with full public involvement</u>.

The role of prescribed fire in wilderness needs to be carefully detailed in the management plan for each specific wilderness area. Although unscheduled ignitions can generally be allowed to burn in fire-dependent ecosystems, scheduled fires need to be far more carefully and specifically managed and, as stated previously, such management requires a precise definition of natural forests.

A natural forest can be defined by the words of the Wilderness Act, quoted above. Its is something far different from what the Forest Service defines as a "healthy forest." I have not seen the latter term explicitly defined but can infer from the management practices designed to achieve a healthy forest that such a forest is roaded and that within it all mature and overmature timber is harvested, burning and other practices are used to improve wildlife habitat and water yield, and large areas are made accessible for motorized recreation. These practices convert a natural forest to a healthy forest. A healthy forest therefore could be called unnatural, but I do not believe we could call a natural forest unhealthy, or we would have to concede that all forests of the world were unhealthy until human beings came along and modified them.

One concept of the natural forest has been developed by disciples of Clementsian ecology, who believe strongly in the climax forest, the primeval forest of poetry. Wilderness buffs are accused of wanting to restore our forests to this ideal state. Hugh Raup, my mentor at Harvard and the manager of the Harvard Forest, made a career of proving that such conditions do not exist and anyone who believes this or seeks to achieve it is misguided. Natural forests, he proves, vary greatly and are disturbed by a series of natural forces that we might consider disasters: hurricanes, fires, disease. They seldom achieve the blissful state of climax. Let me say that TWS fully accepts Raup's viewpoint.

How does this concept affect the effort to define natural forest? As Raup has shown, fire-dependent ecosystems vary by soil, aspect, and climate, to name just a few distinguishing characteristics. Some areas may have burned over every few years; other nearby areas seldom if ever. These differences produce varied, diversified forests that we need to learn more about. It is only logical to proceed by learning more and building on knowledge rather than by establishing a specific definition to which all natural forests must conform.

PUBLIC INVOLVEMENT

Lastly, public involvement must be a principal part of the wilderness fire management process. Managers must get people involved and let them know what is being done and why. Having their ideas and their support will prevent problems. If the public is made aware of the problems associated with fire in wilderness, agreement on solutions should not be difficult.

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FIRE MANAGEMENT POLICIES AND PROGRAMS: AN INDUSTRY VIEW

Howard McDowell

ABSTRACT: The recreation industry may be most affected by wilderness fire activities. The forest industries, miners, and ranchers may also be affected but to a lesser degree.

INTRODUCTION

It should come as no surprise to you that the forest industries and other user groups that earn their living from the forest resource have not considered wilderness fire management to be critical to the health and well-being of those industries and groups.

There is one notable exception: the recreation industry, particularly packers, guides, and outfitters and their clients. They are wilderness users; and as fire or other management programs and policies increase or diminish the clients' enjoyment, they impact their profitability.

On the other hand, the forest industries profitability, spelled s-u-r-v-i-v-a-l, is not measurably affected by wilderness fire management.

Numerous actions by the administrative, legislative, and judicial branches of government keeps us totally occupied with these issues. As a result, individuals in the industry have spent little time examining the subject of fire in wilderness and therefore have not taken strong positions. Although wilderness fire management is not a critical issue in our business, it does have relevance because the effects of such management (or nonmanagement) do not stop at wilderness boundaries.

One of our foresters, Wayne Ludeman, addressed the impacts of resource management programs and policies at the recent wilderness symposium in Moscow, Idaho. In discussing insects, disease, and fire, he said:

> We're also concerned that heavy fuel buildup resulting from mountain pine beetle epidemics and extensive tree mortality on wilderness lands will create the potential for catastrophic fires originating in wilderness areas. Neither insects, disease, nor fire respect property lines. All have the potential to significantly impact management options on adjoining non-wilderness forest lands.
>
> I'd like to note that major fires developing in heavy accumulations of dead timber within wilderness areas also have the potential to seriously impact water quality, fisheries resources, and wildlife values both inside and outside the wilderness areas. If you haven't already done so, I'd suggest that you read Elers Koch's history of the infamous 1910 burn to get a feeling for the magnitude of these potential impacts.

Then he made a series of suggestions including the following on fire management:

> Should we allow planned ignition burning (or even low impact timber harvest) in designated wilderness to restore wildlife habitat, to help meet the needs of endangered species, or to minimize the risk of catastrophic fires? We believe that the wildlife carrying capacity of designated wilderness can be increase substantially by judicious use of prescribed burning without significant adverse impact on wilderness values.
>
> We suspect that by prohibiting practices that could lead to recovery of endangered species, existing wilderness legislation may be in conflict with mandates of the Endangered Species Act. We further suspect that these kinds of legal restrictions may needlessly jeopardize our chances of achieving recovered populations. The role of fire management and other direct habitat management practices in wilderness is an issue that must be addressed. I agree with Russ Dickenson's[1] recognition that it may occasionally be necessary to temporarily violate pure wilderness precepts to ensure recovery of endangered species, to minimize the risk of catastrophic natural events, or to otherwise protect the wilderness resource.

Paper presented at the Wilderness Fire Symposium, Missoula, Mont., November 15-18, 1983.

Howard McDowell is recently retired Executive Vice President, Inland Forest Resource Council, Missoula, Mont.

[1]Director, National Park Service, U.S. Department of the Interior, Washington, D.C.

Regarding the issue of smoke management and restricted airsheds, Larry Blasing, our acting executive vice president, recently responded to a U.S. Environmental Protection Agency (EPA request for recommendations. He noted that where federally designated airsheds restrict smoke volumes, there is a potential source of conflict among land or resource managing agencies; between the agencies and private landowners; among agencies, landowners, and smoke-producing industry; and any combination thereof.

An example: In a designated Class I airshed, Yellowstone National Park and the Lee Metcalf Wilderness Area fire management plans both permit wildfires to burn in certain designated areas. The adjoining Gallatin, Beaverhead, and Targhee National Forests have plans to burn logging slash to reduce the fire hazard and for silvicultural purposes. Adjoining private landowners, including Plum Creek Timber Co. (Burlington Northern), also plan to burn slash.

To consider a worst-case situation let us assume that various slash holders plan early fall burns. As they torch the slash, an electrical storm swoops down on the area and sets fires in the park and wilderness area. The resulting smoke degrades the air quality to a point far worse than historic levels for this Class I airshed. Such actions are forbidden by the EPA regulations that are intended to prevent "significant deterioration" described in the Clean Air Act of 1970. In such a case, who is required to do what? Admittedly, this scenario is extremely unlikely; however, such a possibility must be considered and planned for. Dennis Haddow will discuss this later at this Symposium.

There are also the difficulty and danger of creating confusion in the public's mind when our forest fire prevention symbols, Smokey the Bear and his cohorts, actually applaud certain wildfires. I recall some heated exchanges in the early 1970's between former Regional Forester Charlie Connaughton and silviculturist Bill Beaufait. It was especially distressing to those of us who knew them and greatly respected their professional capabilities and qualities. But then, we had and still have some of that same public confusion and resentment when foresters use any type of prescribed burn. Does permitting <u>any</u> relaxation of vigilance in suppressing fires create a feeling among responsible citizens that they need not be quite so careful with <u>their</u> fires in the forest? Over time, will the practice lead to an increasing incidence of human-caused fires on both public and private forest lands.

On another and more esoteric vein is the question of genetic drift as impacted by large fires. A long-term effect has been referred to by Dr. George Howe and needs further review and discussion by the resource policymakers.

That more or less covers the "indirectly affected" forest industry view, but I would direct your attention to at least two other "industry" groups. Miners and grazers may be directly affected because they are currently permitted users within National Forest wilderness areas. Miners may find their operations jeopardized by the "managed fire" policy, but this is unlikely. Grazers would see the forage composition altered, but the effects overall would be negligible because the percentage of animal unit months in wilderness is small. In rare instances, individuals may find their wilderness uses affected substantially, but this is again unlikely.

In summary, it appears that the industry group with the most at stake is the recreation industry--the park-dependent communities and the packers, guides, and outfitters. The forest industries, miners, and grazers are not now seriously affected by current wilderness fire management programs and policies. But many of us in those industries are involved as wilderness users and will maintain our interest in their management on a personal basis.

Section 3. Park and Wilderness Fire Management Issues

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INTRODUCTORY REMARKS--PARK AND WILDERNESS FIRE MANAGEMENT ISSUES //

Charles Philpot

The rapid transition from a restrictive fire suppression policy to a more comprehensive and biologically and economically sound fire management policy has surprised many observers of bureaucratic dynamics. Federal, State, and local organizations responsible for fire protection have made program changes that many would have predicted would not have occured--certainly not within the past 5 to 10 years. Although there are still significant gaps between policy direction and program implementation, the progress is nonetheless impressive.

The wilderness and park natural fire programs that began in the late 1960's and early 1970's were major contributors to this change. These programs were designed to restore fire to ecosystems that had been set aside to perpetuate natural processes in a natural state. Many of the initial programs were based primarily upon professional recommendations; the data base for establishing precise descriptions of the historic role of fire and its effects and the ecological ramifications of possible fire frequencies, sizes, and intensities was limited. Practical decisions were made, necessary constraints were established, and natural fire programs became operational. Kilgore (1982) reports that today there are 16 operational programs within the U.S. Department of the Interior, National Park Service, and 18 within the U.S. Department of Agriculture, Forest Service.

I suggest that if we had waited for answers to the questions raised by today's panel the program would still be in the planning stages.

What are these questions?

- The most basic question is "what is natural?" Is this a scientific or policy question? How does the answer affect a natural fire program?

- Does "natural" include the historical fire attributed to Native Americans? If so, which fires and over what time frame?

- Is lightning the only legitimate fire source for a natural fire program? Or can humans ignite fires without jeopardizing the natural state?

- What aspects of fire behavior, size, and distributions are critical to a natural fire program?

- What exactly is natural fuel buildup, and how should a natural fire program be implemented to account for it?

The Symposium organizers have assembled an impressive group of experts to consider these issues and to provide insight into their significance and possible ways with which to deal with them.

Paper presented at the Wilderness Fire Symposium, Missoula, Mont., November 15-18, 1983.

Charles Philpot is Director, Forest Fire and Atmospheric Sciences Research Staff, U.S. Department of Agriculture, Forest Service, Washington, D.C.

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WHAT IS "NATURAL" IN WILDERNESS FIRE MANAGEMENT?

Bruce M. Kilgore

ABSTRACT: A "natural" fire for any ecosystem is one that (1) burns within the range (and frequency distributions) of fire intensities, frequencies, seasons, and sizes found in that ecosystem before the arrival of technological Europeans and (2) yields the range of fire effects found in that ecosystem before the arrival of Europeans. Park and wilderness land managers must decide whether they primarily want to focus on natural fire process or natural fire effects. Managers and scientists need to work together to assure the maximum possible role for natural fires in wilderness--based on specific fire history data for particular ecosystems and geographic areas (including information on the role of aboriginal burning and knowledge of past fire intensities)--while still giving reasonable consideration to safety of human life and property.

INTRODUCTION

Most of us in park and wilderness fire research and management have often used the term "natural." We say we want to restore the natural role of fire in a given forest or other vegetation type. Or we want to simulate the natural role of fire by prescribed burning at a given frequency and intensity. Yet researchers and managers associated with the earliest natural fire management program in the United States say that a prime need for their future programs is to define what natural is (Bancroft and others, this Proceedings).

What do we mean by natural? Do we all mean the same thing? Should the term be used at all: If so, what exactly do we include as natural? If not, what term should we use in its place?

"NATURAL" DEFINED

The word "natural" has many definitions in the dictionary and many synonyms in the thesaurus. The synonyms that best convey what I feel is natural are intrinsic, pure, untouched, unaffected, inherent, fundamental, basic, original, spontaneous, innate, unvarnished, plain, simple, virginal, and unsophisticated. Perhaps the most useful definitions in a fire management context are these:

1. Living in or as if in a state of nature, untouched by the influences of civilization and society

2. Free from artificiality, affectation, or constraint

3. Having a spontaneousness that suggests the natural world.

Although the Wilderness Act of 1964 does not specifically define natural, it implies a definition when it defines the word "wilderness" "as an area where the earth and its community of life are untrammeled by man, where man himself is a visitor who does not remain." It goes on to add that wilderness is an area of undeveloped federal land "retaining its primeval character and influence, without permanent improvements . . . which is protected and managed so as to preserve its natural conditions and which . . . generally appears to have been affected primarily by the forces of nature, with the imprint of man's work substantially unnoticeable . . . ."

In The Literature

Turning to the fire ecology literature, I found relatively few efforts to characterize what is natural in wilderness fire management. Keeley (1982) defined a natural fire regime as one "unaltered by contemporary or aboriginal man." In an earlier paper (1976), I used "natural" to mean "lightning-caused" when referring to natural fires allowed to burn in higher elevation zones of a park area. Referring to the sequoia-mixed conifer forest of the Sierra Nevada of California, Keeley (1981) defined the natural role of fire as the role fire played during the evolution of species in that ecosystem. Kilgore and Taylor (1979), however, implied that the high-frequency, low-intensity fires found in that forest between 1700 and 1875 (and probably since A.D. 400 or before) constituted the natural role of fire in that forest--a role in which lightning ignitions have been considerably augmented by aboriginal burning.

Franklin (1978) defined "naturalness" as the freedom from significant influences of modern technological man. He pointed out that modern man's activities can affect various key attributes of ecosystems--their functional ability, structure, composition, and basic successional patterns--and

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that the ecologically most significant human alterations of natural systems, such as changes in long-term successional patterns and capacity to cycle energy and nutrients, may not be the most obvious. He also discussed some fundamental questions about whether man and his influences are natural in wilderness. He distinguished between aboriginal man who did not exist in sufficient numbers nor have technology to control nature, and modern man who does, and concluded that

> "Natural" human influences might be considered those which have been elements in the long term evolution of the presettlement ecosystems--present for hundreds, thousands, and even tens of thousands of years . . . . [but] we cannot accept modern man--or more specifically the forces he controls--as a "natural" component of wilderness.

Heinselman (1973) seemed to mean only lightning ignitions when he defined "natural fire rotation" as the time needed for a natural fire regime to burn over an entire large unit. Elsewhere (Heinselman 1978), he argued that using lightning-caused fires as part of our management programs allows nature to select the time, place, vegetation, and fuels for fires. When deliberately ignited prescribed fires are substituted for lightning-caused fires, however, we have to assume that ecological effects will be the same. Van Wagner and Methven (1980) support this assumption, but Heinselman (1978) warned that unless prescribed fire is used skillfully, we may burn at the wrong season or too frequently.

Heinselman (1978) further defined the objective for most wilderness fire situations as: "To restore fire to its natural role in the ecosystem to the maximum extent consistent with safety of persons, property, and other resources." This does not mean trying to achieve any specific set of values for wildlife or for fuels, nor does it pertain to specifics regarding acres of certain types or age classes of vegetation. Instead, it aims to restore the naturalness of the ecosystem; whenever possible this should be achieved by letting natural processes reestablish themselves (Heinselman 1978). The only way this can be done is for the manager to know as much as possible about what the natural role of fire actually was, including the clearest possible outline of the presettlement fire regime.

Expressing a different point of view, Van Wagner (this Proceedings) defines "natural" as "any factor that has been in effect long enough for the vegetation to come into equilibrium with it." The natural fire regime at the time Europeans first arrived often would have included both lightning fires and Indian (Native American) burning. In addition, Van Wagner raises a basic question about our objectives in wilderness fire management: Are we looking for fires ignited under the conditions and means found in primeval times or are we looking for vegetation that a natural fire regime would have created? This question relates strongly to the interpretation given to the 1963 Leopold report (Leopold and others 1963): Are we looking for a static vignette of primitive America or a dynamic ecosystem that would have evolved from that vignette had we not made major changes with fire suppression?

I personally favor vegetation that a natural fire regime would have created and a dynamic ecosystem that would have evolved from the primeval or pristine situation, and I strongly hope managers and researchers will come to some consensus on these questions in the near future. Because as Mills (this Proceedings) notes, there is a pressing need in park and wilderness management for "a clear articulation of what the objective of recreating a 'natural' state really means." He feels very different management programs may be needed if the objective is to produce a desirable set of outputs (such as wildlife habitat and nutrient flow) rather than to re-create a "natural state" having an intrinsic value in and of itself. The second alternative would be comparable to preserving an archeological site or perpetuating a living system for scientific study. In line with this concept of natural, many who devoted themselves to passage of the 1964 Wilderness Act believe that "Wilderness areas are assumed to represent natural templates against which man-made imbalance can be measured; genetic banks, where natural species and natural ecosystems retain molecularly coded wisdom acquired over eons of evolution; unspoiled sanctuaries, esthetically pure and uncontaminated by the impediments of civilization" (Pyne 1982). We recognize, of course, that because of global pollution (for example, acid precipitation, chlorinated hydrocarbons, CO_2 buildup), and because we have established relatively small boundaries on wilderness ecosystems, pure naturalness is not attainable within our heavily civilized biosphere. We already manage and affect a major portion of the earth's landscape, and no ecosystem is totally isolated from the effects of our technology. Nevertheless, our parks and wildernesses probably represent the closest approximation to naturalness available today.

A SURVEY OF EXPERTS

Because defining the term "natural" has not been a major focus in the literature, I sought the wisdom of a cross-section of 97 knowledgeable scientists and managers involved in the study or management of wilderness or natural fire programs in forest and other vegetation types. I talked to 85 people in the U.S. Department of the Interior, National Park Service, Bureau of Land Management, and U.S. Fish and Wildlife Service; U.S. Department of Agriculture, Forest Service; as well as government agencies in California, Canada, and Australia. Also included were segments of the university fire research community from the Northern and Central Rocky Mountains, California, and the West Coast, and personnel from the Lake States, Midwest, and Southwest.

I asked each person seven questions (see appendix) about how they would define the word "natural" as applied to the role of fire in vegetation ecosystems and how they would relate that definition to Indian burning versus lightning ignitions, fuel accumulation following past fire suppression, and the policy question of whether high-intensity, stand-replacing fires should be allowed to burn in park and forest wilderness units under certain conditions.

I could find no clear distinction among the responses of personnel from different agencies nor between scientists and managers from a given agency. Instead, there were many similarities among the statements given by government agency personnel and university fire scientists and yet considerable diversity overall. The following are common responses to the question, "What do you feel is meant by the word 'natural'?":

1. Pre-European or pretechnological man, or presettlement. This apparently includes all non-anthropogenic fires and all Indian fires--fires that were unhampered by modern man's influence and occurring at historic intervals, intensities, seasons, and sizes that would have occurred had technological man--including colonists, miners, and pioneer settlers--never modified the ecosystem.

2. Without human intervention or influence. This would mean ignitions solely from lightning (or in some cases volcanoes) that are allowed to function without human interference. Some add the caveat, "except as dictated by safety and protection of resources."

3. The attributes of the fire process known or presumed to be an intrinsic part of a given vegetation type. These attributes include frequency, intensity, size, season, and distribution. For some, this means accepting fire on its own terms and allowing nonhuman-caused fires to burn within the range of frequencies, intensities, and burn patterns found in pre-European times or during the prehuman evolution of the system.

4. The role fire played in the evolution of an ecosystem. As an agent of change, fire--like wind, insects, and disease--has been a disturbance factor throughout time. This means fire has influenced natural selection, ecosystem structure, and distribution of plant and animal populations.

The question of what is "natural" in wilderness fire management can be rephrased a number of ways to illustrate the complexity of the issue and the interrelationships involved:

1. When did (or does) fire perform its natural role in a given ecosystem? Only during evolution of the system to the present state or also during the pre-European (aboriginal) period and today?

2. What constitutes the natural role in a given ecosystem? Is it the process, involving frequency, intensity, season, and size of fire, including the ignition factor? Or is it the effects on the ecosystem--particularly the vegetation?

3. How important is the ignition source in determining whether fire is natural? Are the results of lightning fires in a national park or wilderness always natural even if fuel accumulations are unnatural? Are the results of an escaped campfire always unnatural even if the effects are within the range of past fire impacts? Are results of a prescribed human-ignited fire always unnatural if they have been planned to coincide with the frequency, intensity, season, and distribution found to have been typical of the past 300 to 30,000 years in a given ecosystem?

Table 1 compares natural and unnatural conditions of fuel and fire characteristics in a sequoia-mixed conifer forest and shows how these somewhat nebulous terms might be made more specific for a particular ecosystem. Using 39 years as the longest interval between fires found in a study of a particular unit (Kilgore and Taylor 1979), we can calculate the reasonable maximum surface fuels and ladder fuels that could accumulate here under a natural fire regime. One logical question under these circumstances would be, "How likely is it that a natural lightning ignition occurring in such an area after 70 to 100 years of fuel accumulation will result in natural fire effects? It appears that if any of the listed characteristics (fuels, fire, or vegetation) are in an unnatural condition, it will be difficult to achieve natural results from fires burning in those unnatural conditions, even if all other factors are in a natural condition.

In summary, the basic issue is whether an ignited fire (1) burns within the range (and frequency distribution) of intensities and frequencies, (2) achieves the same range of sizes, and (3) burns at the same seasons in which fires burned during the past 15,000 years when the present vegetation mosaic and forest structure were developing. It does not seem to matter whether the ignition source is human (prescribed fire or even unscheduled ignition) or lightning, so long as the effects it achieves are the same or simulate the same range of effects that have occurred in the past. The chances are perhaps greater that lightning or volcanic ignitions will occur within the historic pattern to which the ecosystem has been subjected over the past hundreds, thousands, or even millions of years; human-caused ignitions arising from campgrounds or other localized heavy human-use sites would occur in a far less natural pattern. If, however, we can learn to simulate that historic pattern, the impacts of prescribed burns may be similar to those of lightning-ignited fires. To a large extent, the burning patterns are determined by size and distribution of fuels and fuel moisture conditions anyway--variables controlled largely by weather and other environmental conditions over which humans have little control.

Table 1.--Theoretical comparison of "natural" and "unnatural" fuel and fire characteristics in a sequoia-mixed conifer forest

Fire or vegetation characteristics	"Natural" condition	"Near-natural" condition	"Unnatural" condition
FUELS			
Surface[1]	Less than annual accumulation X maximum years (39) between fires in that system	Maximum "natural" amount ± 25%	Greater than maximum "natural" amount
Ladder[1]	Few individual white fir and aggregations of white fir that exceed 39 years of age (large proportion killed by frequent surface fires)	Moderate number of white fir individuals and aggregations that exceed 39 years of age; few aggregations beneath sequoia and pine exceed that age	Numerous white fir individuals plus aggregations, both in openings and beneath sequoia and pine, that exceed 39 years of age
FIRE			
Frequency	Clusters of living trees scarred by fires every 5 to 18 years (maximum interval = 39 years)	Clusters of living trees show fire scars at least every 20 to 40 years	Only isolated scar or two recorded by clusters for the past 70 to 100 years
Intensity	Fires are small and of low intensity	Fires are relatively small but occasionally torch pine and sequoia where ladder fuels have accumulated	Fires cover larger acreages--more than a single drainage--and tend toward higher-intensity torching of crowns of both sequoia and pine
Season of burn	Summer and early fall	Spring	Late fall and winter
Ignition source	Lightning and aboriginal burning during presettlement time (approximately A.D. 400 to 1870)	Prescribed fire is used to simulate natural pattern in combination with lightning	Human-caused without any "natural" objective
	Lightning alone during evolutionary period		
VEGETATION			
Mosaic patterns[1]	Intricate mosaic of age classes and vegetation subtypes		More uniform age classes with less mosaic pattern

[1]Concepts adapted from data in Kilgore and Taylor 1979.

IS INDIAN BURNING "NATURAL?"

Nearly half of the people contacted felt that Indian burning was natural, a third felt it was not, and 20 percent were not sure. Those who said it was natural made the following points:

1. The Indian derived energy internally within the ecosystem and lived in harmony with the land, with no intention of conquering it. Human actions became "unnatural" only when the means to drastically alter the environment became available.

2. We have traditionally accepted presettlement vegetation and the original inhabitants as natural. We cannot separate lightning from aboriginal fires in the ecosystems we view; fires started by Indians had the same ecological effects as fires started by lightning.

3. In most areas of North America, Indians were involved with fire for some 4,000 to 10,000 years or more--long enough to qualify as "natural." Vegetation has responded to this practice over a long period--almost as long as some forest types have existed following the

Wisconsin glaciation (many thousands of years in the South and East; perhaps only 1,000 years in California). Plant composition and density have evolved under conditions that include this "stress" or altering impact.

4. Increased ignitions no doubt shaped vegetation mosaics and forest structure first described by settlers. Without Indian ignitions, the lower fire frequency would have resulted in different vegetation distribution from that found in prehistoric times.

5. The objectives targeted by most park and some wilderness management personnel (maintaining vegetation as it was when Europeans arrived) aim to simulate the time period when native people were significant ignition sources. If we want ecosystems to look like those affected by Indian burning, we need to introduce that level of burning--whether natural or not.

Those who felt Indian burning was not natural listed their reasons:

1. Natural means started by nature and excludes human influences. Indian burning is a conscious act and therefore an artificial intrusion. Indians burned with an objective or purpose, just as we do.

2. Such burning was not a significant long-term force in species or ecosystem evolution and influenced species adaptation for only 10,000 years. Plant types were adapted to fire long before the Indians arrived. Although Indian fires influenced vegetative mosaics, so do modern wildfires. In addition, relatively small acreages were burned and could only have local significance.

3. There is no way to clearly separate primitive humans from technological humans, unless the ability to use fire permits the distinction. We have to draw the line somewhere.

4. Whether Indian burning is natural is the wrong question. What we really need to know is, "Is there a change from historical fire behavior if lightning fires are the only source of natural fire?" If not, the effects of Indian burning duplicate those of lightning fires.

Nearly half of the people contacted felt the Park Service should simulate Indian ignitions, about 21 percent felt they should not, and 30 percent were not sure. Those who felt Indian ignitions should be simulated included the following reasons:

1. The historic record intertwines lightning-caused and Indian-caused fires, so we cannot know precisely how much influence Indians had. Because most parks need extra ignition to make up for fewer lightning fires from outside sources as well as from Indian sources, we need the best records possible of total past fire frequency. We must then be sure the combination of lightning and our simulation (prescribed burning) efforts do not exceed the established historical frequency or fire cycle.

2. If the National Park Service goal is to reestablish and maintain vegetation representing conditions when Europeans first arrived, simulating Indian burning is the only way to move toward this condition. Lightning alone will never reduce the fuel buildup generated over the past 100 years and may move the system further away from the objective, particularly where fuel buildup is excessive and the probability of unnatural stand-replacing fires is high.

3. Grassland types may have existed precisely because of Indian burning, and burning may be essential to maintain them. Such burning may be needed only in limited areas where anthropogenic fire was particularly significant and where we can demonstrate that lightning alone cannot re-create natural vegetation patterns and structure.

4. Pragmatically, the National Park Service should decide on the desired mosaic and manage an area accordingly. Appropriate practices may or may not simulate Indian ignition. We should aim for a regime that is somewhere between allowing all lightning fires to burn and simulating Indian burning and that is feasible in terms of economics and human safety. Present-day landownership precludes allowing a "natural" fire to burn as intensely as some presettlement stand-replacing fires did, and simulated Indian burning may minimize such a result.

Those who felt we should not simulate Indian ignitions had fairly strong feelings and strongly worded objections:

1. It has not been demonstrated that Indian burning played a "significant" role in altering forest ecosystems, although it may have increased frequencies somewhat locally, favoring fire-adaptive, shade-intolerant species.

2. We will never have sufficiently accurate data to simulate the extent, season, and intensity of Indian fires. Hence, we would not know exactly when, where, and how Indians burned and would have to play God.

3. We do not simulate other factors that have changed--extirpated plants and animals, Indian hunting, and Pleistocene glaciers. Why select Indian fire?

4. Lightning fires were a major ignition source for millions of years, whereas Indian influence in such areas as the Sierra Nevada of California lasted only 800 to 1,000 years. This short period before Europeans arrived is minor in evolutionary or ecological terms.

5. Simulating past Indian burning would ignore cultural changes that have taken place over time and would amount to preserving an artifact; systems must be free to evolve. Which Indian fire

culture would we simulate--that frozen in time in the mid- to late 1800's? It is better to simulate presettlement fire regimes that do not distinguish human ignitions from other ignitions.

6. What is our goal or objective? Do we want to maintain processes as they existed before Europeans arrived or before all human beings arrived? Do we want the natural role of fire or the cultural-historic use of fire?

7. In areas such as the Sierra Nevada of California, fires have typically been frequent surface fires, and fuels, therefore, do not accumulate to the point of involving crowns routinely. If this pattern of frequent ignitions remains constant with lightning ignitions alone, the impact on vegetation will be the same as when both Indians and lightning were involved.

8. Finally, at least one respondent felt that we have come too far from aboriginal days to expect society to accept simulated Indian fires in parks and wilderness.

WHAT ABOUT LIGHTNING FIRES?

Of those who felt that Indian ignitions were not natural, about one-third were willing to allow lightning fires to burn, even if fuel accumulations would mean higher intensity burning than had been the case during the past 200 to 500 years with both lightning and Indians starting fires. Some 40 percent were against such burning, and 27 percent were not sure. Those who favored letting lightning fires burn felt that:

1. The ecosystems have evolved with such perturbations and have survived several periods of increased or decreased fire frequencies; their resiliency will allow recovery in spite of these cyclical changes.

2. There were no Indians in North America before 15,000 to 30,000 years ago, which means that heavier fuel loads would have resulted from climatic variations, insect outbreaks, windthrows, avalanches, and other conditions.

3. High-intensity fires are acceptable as long as they do not threaten the public or developments and are contained within park or wilderness units.

The 40 percent who opposed allowing lightning fires to burn in situations where lack of Indian ignitions may have permitted abnormal fuel accumulation expressed the following concerns:

1. If suppression has created abnormal fuel levels, we initially need to use prescribed burning to reestablish fuels that resemble those found under a natural fire regime. Simply letting lightning fires burn would not be "natural," particularly in places where they would result in stand-replacing crown fires, where only underburning occurred before.

2. Although some early fires may have been scorchers, we do not have enough public land left to permit such experimentation under certain adverse weather conditions. In some situations, preserving rare community types is reasonable whether accomplished by natural or unnatural means at the outset.

3. A program that allows all lightning fires to burn will not stand the test of public scrutiny. An agency's credibility would be suspect if it relied only on lightning fires because it felt Indian fires were not "natural." To some extent, politics and human safety will ultimately dictate the solution.

HIGH-INTENSITY NATURAL FIRES

When respondents were confronted with the question of how to handle high-intensity, stand-replacing crown fires, 71 percent philosophically favored letting such fires burn if they are part of the fire history of a given ecosystem. Nearly all, however, gave a "yes, but" answer. They felt this type of fire was essential for effectively maintaining certain vegetation types and should be allowed to burn <u>when feasible</u>. Although letting such fires burn is somewhat risky, they felt suppressing them all would appear contrary to the natural system. The strongest reservation about such a policy was based on the need to safeguard human life and property, including visitor facilities. Concern about neighbors' lands led to the feeling that such fires must be extinguished if it is likely that a crown fire will extend beyond the boundaries of a park or wilderness. It became clear that such fires could be allowed to burn only in very large and remote parks and wilderness units with buffer zones around them. Thus, although it was easy for many to say yes to allowing high-intensity fires to burn because it seemed ecologically proper, it is hard to carry out such a program practically--and perhaps politically impossible in many areas.

Even those who supported a program allowing high-intensity fires to burn tended to include an initial program of prescribed burning for fuel reduction. One person suggested using prescribed fires to take the place of "orphan" fires that start outside wilderness areas but are suppressed and never get all the way "home" to wilderness as they have in the past. Important considerations in such a program seem to be wilderness size, values on adjacent lands, and visitor use patterns in parks and wildernesses. Defensible unit boundaries seem a key concern.

A sizable minority showed a healthy skepticism about whether such a program is practical or can be tolerated at all today. Their main concerns were these:

1. High-intensity crown fires are too hazardous to be permitted to burn for long. We can permit only low- or moderate-intensity fires--either by scheduled or unscheduled ignitions. If

high-intensity, stand-replacing crown fires are natural and needed in certain vegetation types (for example, knobcone pine), prescribed fires should fulfill this need.

2. There are not enough areas in parks and wildernesses to permit uncontrolled crown fires. The present distribution of fuels would permit larger fires than occurred naturally before the arrival of Europeans. Social, economic, and political pressures will dictate some substitution of controlled fire, naturally or human-ignited, for high-intensity crown fires.

3. Threat to human life makes it impractical to accept such fires. If fire managers have the courage to push the prescription to an extreme, perhaps they can get results that are close to high-intensity, stand-replacing fires. This would mean being prepared to lose some fires occasionally.

4. Allowing severe fire treatments over large areas during the height of the fire season could be dangerous to adjacent nonwilderness areas, would be expensive, and might lead to backlash against use of fire. In view of the physical, financial, and social constraints involved, land managers should instead use prescribed burns under carefully planned conditions.

It would seem, therefore, that both groups find that prescribed burning is necessary, at least initially, in a program that restores the opportunity for high-intensity, stand-replacing fires to assume their natural role in park and wilderness ecosystems. This is seen to be somewhat more natural than allowing fires to burn only during weather and fuel conditions that would permit only low- to moderate-intensity burning.

DISCUSSION

Several respondents felt that trying to define natural was absurd. One noted,

> I don't think there is such a thing as a truly natural landscape anywhere on earth today . . . . It seems to me that there needs to be a decision as to what kind of man-modified landscape we want in the future, followed by efforts to develop better ecologically sound measures to attain them. This is likely to be far more satisfactory in the long run than sterile arguments about what is "natural."

Others also preferred not to use the term and chose instead to define the number of acres of certain-aged stands or vegetation types or the numbers of deer and elk we want to aim for.

Although I can understand these preferences on the part of scientists or managers, I do not think our objectives will ever be that easy to specify or that objectives can be divorced from the philosophical underpinnings of national park and wilderness area management. The original reasons for establishing these areas were broad and philosophical; I see no way we can now define them in specific numerical terms, although perhaps we can gradually convert these broad concepts into approximate quantitative equivalents.

As an example, Bonnicksen and Stone (1982a) concluded that the present structure of the giant sequoia-mixed conifer forest community in Kings Canyon National Park, Calif., is considerably different from that found in the presettlement period (before about 1875 or 1890) because of fire exclusion. They presented alternative approaches based on aggregation theory for restoring "natural conditions," which they defined as the presettlement conditions, or the conditions that would have existed if European settlers had not interfered with natural processes. They recommended a "reconstruction-simulation" approach (Bonnicksen and Stone 1982b) as the "most efficient and least obtrusive means to restore natural conditions." This approach involves (1) obtaining a detailed description of the presettlement forest community that describes the area occupied by different types of aggregations; (2) simulating vegetation changes that would have occurred in the absence of European settlers' influence; (3) using the projected present state as target vegetation conditions (described in terms of area occupied by different types of aggregations); (4) developing management plans to achieve those conditions; and (5) once target conditions are reached, allowing vegetation to change without further intervention under the influence of natural and simulated natural processes. Their recommended approach is based on the principle that "natural processes . . . cannot be preserved in unnatural vegetation because the functioning of an ecosystem is clearly inseparable from its structure."

Park and wilderness land managers must decide whether they primarily want to focus their attention on (1) <u>natural fire process</u>--a set of fires ignited and burning the same way as fires in the original natural regime; (2) <u>natural fire effects</u>--the vegetation that a natural fire regime would have created; or (3) some other objective. The first two are closely related--some would say inseparable. So after a substantial time without the process (allowing an unnatural buildup of fuels and perhaps species and age-class changes in certain areas), simply letting the lightning fire process begin again will not ensure attaining the natural vegetative effects once directly connected with the natural process. As Pyne (1982) noted, the return of the natural lightning process to such modified wildlands "is less likely to 'restore' an ancient landscape than it is to fashion a landscape that has never before existed." The problem is that many of our wilderness and park areas are not yet back to a natural condition (Phillips, this Proceedings) and therefore, for a variety of practical reasons, we are not in a position to allow most natural fires to burn.

Instead, the initial objective of many natural fire programs may need to be to reduce fuel accumulations through carefully planned prescribed burns and return the ecosystems to a condition approximating the one they would be in had fire suppression and landscape modification in areas surrounding national parks and wilderness areas not taken place (Parsons 1981). In all likelihood, we will never be able to restore ecosystems totally. We can only approximate what they would have been. For example, concern has been expressed that without fire for the past century in certain ecosystems, some understory plant species may have disappeared, new species may have appeared, and mature conifers may now have substantial portions of root systems growing in forest floor organic material--a situation never before found in such systems. The fear is that although we can simulate presettlement fire frequency and even fuel accumulation, we may never be able to totally simulate certain effects (Harrington 1983). This may be, however, the best we can do. The amount of area burned each decade and the timing of repeat burns should be based on actual fire history (Alexander and Dubé 1983). "If planned ignition prescribed fires are used exclusively, then the ignition patterns, the size of areas to be burned, timing, and frequency of burning, etc., are critical" (Heinselman 1973; Alexander and Dubé 1983). To the extent that fire frequency, intensity, and timing mimic the natural regime, the resulting fire effects should be as natural as possible (Heinselman 1978). Good judgment will need to be used in deciding whether fall ignitions should initially be substituted in situations where summer burns were found historically, but where "unnatural" structural changes in the ecosystem make such burns undesirable at the outset.

Lightning is considered by some to be the primary fire starter in many regions, and aboriginal humans are not considered to have added significantly to the area burned or to have altered the natural cycle and timing of fires (Heinselman 1978). Based on recent work in the Big Woods of Minnesota, Grimm (1984) disagrees, saying that had Indians not been present in the area, the frequency of fires would have been much lower and the vegetation much different. He notes that "Indians were a highly regular, predictable source of ignition; whereas lightning storms are highly irregular, unpredictable, and in any case infrequent during the seasonal drought periods when most of the fires occurred."

To help solve the fire management dilemmas facing park and wilderness fire managers in the next few decades, there is a great need for specific baseline data dealing with fire history of a particular forest ecosystem and a particular geographic area--including information on the role of aboriginal burning and knowledge of past fire intensities. The 1980 fire history workshop in Tucson, Ariz., reported on the status of fire history studies in many areas, some of which involved parks and wilderness areas (Stokes and Dieterich 1980). The most current bibliography of fire history studies is by Mastrogiuseppe and others (1983). Additional studies have recently been initiated or completed in a number of park and wilderness units, including Glacier National Park, Mont., and the River of No Return Wilderness in Idaho. More such studies are needed to support management decisions on programs involving planned (scheduled) or "random-ignition" (unscheduled) (Alexander and Dubé 1983) prescribed fires.

These studies will be especially valuable when deciding how to apply various philosophical and ecological concepts, including situations where high-intensity crown fires have been part of the historical natural fire regime, because "conflicts between ecological processes and social concerns hinder widespread application of 'wilderness' fire management concepts and principles. Concern for human safety and adjacent lands severely restricts the management of fire on the scale required" (Alexander and Dubé 1983). Managers and scientists need to work together in the next few decades to assure that management of parks and wilderness units encourages the maximum possible role of natural fires while still giving reasonable consideration to the safety of human life and property.

CONCLUSIONS

The term "natural" as applied to park and wilderness fire management usually means (1) fire occurring during the pre-European, pretechnological, or presettlement periods; (2) fire occurring without human intervention or influence; (3) the attributes of the fire process known or presumed to be an intrinsic part of a given vegetation type; or (4) the role fire played in the evolution of an ecosystem. The following definition, developed in this paper, involves both the fire process and the resulting effects:

> A natural fire for any given ecosystem (1) burns within the range (and frequency distributions) of fire intensities, frequencies, seasons, and sizes found in that ecosystem before arrival of western technological innovations and (2) yields the range of fire effects results found in that ecosystem before the arrival of technological man.

In contrast to this:

> An unnatural fire (1) burns outside the same range (and frequency distributions) of fire intensities (for example, overly high intensity); frequencies (for example, too rarely); seasons (wrong one); and sizes (too large) and (2) yields fire effects that go beyond the range found before technological man (that is, a stand-replacement fire, where underburning is the usual pattern, with soil erosion and elimination of certain species from the ecosystem).

The National Park Service and Forest Service are committed to maintaining or restoring the integrity of our natural and wilderness ecosystems down through a long future. In the words of the 1963 Leopold report: "A reasonable illusion of primitive America could be recreated using the utmost in skill, judgment, and ecologic sensitivity." That objective can only be accomplished when there is a better understanding of the importance of the past fire history or natural fire regime in individual vegetation units and geographic sites and when the best possible knowledge is applied with judgment, commitment, and skill to each national park or wilderness unit in the country.

The senior author of the original Leopold report, the late Starker Leopold of the University of California, Berkeley, made an observation in the summer of 1983 on the question of natural versus aboriginal ignition of fires in national parks that is worth considering by scientists and managers of any agency (Leopold 1983):

> If the area is ready to burn, it makes little difference . . . whether the fire is set by lightning, by an Indian, or by [a park scientist], . . . so long as the result approximates the goal of perpetuating a natural community . . . . Our parks are too small in area to relegate to the forces of nature that shaped a continent . . . . Management issues of this kind involve judgment, followed by action. They are not resolved simply by allowing natural ecosystem processes to operate. I still espouse the idea of active manipulation to maintain a more or less natural aspect to the park as seen by the visitor . . . . It is OK to manage the back country as wilderness (as per Hendee et al.), but the foreground should not be left to chance. It deserves intensive, ecologically skillful management.

It is important to all future Americans that scientists, managers, and environmentally concerned citizens rise to the challenge of that statement. Our discussions in this Symposium about Indian burning, the choice between lightning- and human-ignited fires, fire size and intensity, unnatural fuel buildup problems, data base needs, economic considerations, planning and operational techniques, and air quality should go a long way toward assisting us in focusing on the knowledge presently available to make these important wilderness fire management decisions.

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APPENDIX: Questions Asked of People Contacted

With respect to national parks and Forest Service wilderness, what do you feel is meant by the word "natural" when you hear (or say):

1. We need to restore the "natural" role of fire to this forest (or other vegetation/habitat type).

2. Fire plays a "natural" role in this forest ecosystem.

Your opinion would also be appreciated on these related questions:

3. In particular vegetation types where aboriginal man (Indians) were known to start fires, do you feel such Indian burning was "natural"? Why?

4. In restoring the "natural" role of fire to a national park ecosystem, should the National Park Service simulate the role of Indian ignitions (presumably by human-ignited prescribed burns) as well as allow lightning fires to burn?

5. If you feel Indian ignitions were not natural, would you favor allowing lightning fires to burn if the fuel loads between ignitions (and hence fire intensities) become much greater than those found during the past 200 to 500 years when both lightning and Indian ignitions were starting fires?

6. If high-intensity, stand-replacing crown fires are found to be part of the fire history of a given forest ecosystem in a national park or Forest Service wilderness, would you favor allowing such fires to burn? Or would you suppress them and (a) allow fires to burn only during weather and fuel conditions which would give low- to moderate-intensity burning or (b) use prescribed burning under controlled conditions to simulate the presettlement role of fire?

7. In an evolutionary sense, should "natural" include just lightning and volcanic ignitions? Or should aboriginal man's early use of fire also be included in the role fire played in achieving various adaptations to fire in such species as giant sequoia, ponderosa pine, Douglas-fir, chamise, and others?

INDIAN FIRES IN THE INTERIOR WEST: A WIDESPREAD INFLUENCE

George E. Gruell

ABSTRACT: Changes in fire frequency has significantly influenced successional development in the Interior West. The implications for resource managers depends on whether Indian fires significantly augmented fires caused by lightning. An examination of the historical literature suggests that Indians were responsible for many fires, thus contributing to the high fire frequency that was common at lower and middle elevations before Euroamericans arrived. Recent photographs of Interior West areas show successional development that differs significantly from that shown in photographs taken a century earlier, when the vegetal effects of Indian fires were still evident.

INTRODUCTION

In earlier studies (Gruell 1980; Gruell 1983), I compared photographs taken of landscapes in the Middle and Northern Rockies between 1871 and 1982 and observed that the vegetation shown in early and late photographs differed significantly. A more open landscape, snags, and fire mosaics in many of the original photographs showed that in earlier years fire had significantly affected vegetation. Various fire history studies support this interpretation.

Other photographic studies in Utah (Rogers 1982), Montana (USDI, BLM 1979, 1980), Montana and Wyoming (Phillips 1963), Wyoming (Houston 1982), and northwestern South Dakota and northeastern Wyoming (Progulske 1974) also document changes in vegetation patterns over the past 50 to 100 years. In earlier years graminoids and herbs dominated; shrubs and trees became more prevalent in later years. In places where this trend occurred, fire frequency usually had decreased markedly.

To better understand this pattern, I began in 1978 to assemble and interpret historical narratives describing vegetation burning in the Interior West (Montana, Idaho, Wyoming, Utah, Nevada, and eastern Oregon). Previously no one had attempted to organize and analyze historical accounts of vegetation and fires in the region. For resource managers, the implications of this research would depend in part on what caused the fires. Although lightning was obviously responsible for many fires, it could not be blamed for the great number of fires that occurred. The historical narratives I examined contain numerous firsthand accounts of fire and burned landscapes, and many indicate that Indians started the fires (Gruell in press). In this paper I examine evidence that supports this possibility.

PREVIOUS RESEARCH

Worldwide historical records examined by Stewart (1963) left little doubt that primitive hunting and gathering peoples frequently and intentionally set fire to vegetation. Literature reviews by historians and geographers have also shown that human-ignited wildfire was a general feature of primitive societies (Sauer 1980; Pyne 1982). By utilizing fire, primitive peoples controlled their environment to some extent (Nelson and England 1971) and thus survived under adverse conditions.

Historical accounts indicate that Indian fires occurred in all major geographic areas of the United States (Stewart 1951). These accounts have been corroborated by regional studies in the central North American grasslands (Moore 1972), northern Great Plains (Loscheider 1975), the central Sierra Nevada of California (Reynolds 1959), California (Lewis 1973), eastern Oregon (Shinn 1980), and western Montana (Barrett 1981). Stewart (1963) concludes that the great number of such reports establishes that Indian fires were an important ecological factor that should not be overlooked.

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Some scientists, however, question whether the historical record is accurate enough to implicate the Indian as a major cause of early fires. Russell (1983) concluded that fires intentionally set by Indians in northeastern forests were probably at most a local occurrence. Burcham (1959) believed that in California Indian set fires were uncommon even before Euroamericans arrived.

Research in western Montana and east-central California has provided detailed information on Indian-caused fires, including their frequency and effect on vegetation. Barrett (1981) investigated Indian fires in western Montana lower elevation (2,000-6,000 ft [610-1 829 m]) ponderosa pine/Douglas-fir (*Pinus ponderosa/Pseudotsuga menziesii*) forests through interviews, historical journals, and fire scar sampling. The fire scar data from paired stands indicated substantial differences in fire frequency between Indian habitation zones and uninhabited areas before about 1860. The scar data and historical narratives suggested Indians were largely responsible for the higher fire frequencies that characterized stands in habitation zones. In addition, repeat photography in a former habitation zone in Barrett's study area, the Bitterroot Valley, clearly shows that conifers and shrubs have increased markedly since the virtual elimination of fire after 1900 (Gruell and others 1982).

Examination of fire-scarred stumps in a mixed-conifer forest on Redwood Mountain in the California Sierra Nevada showed a mean fire interval of 5 to 8 years from 1700 to 1875 (Kilgore and Taylor 1979). Kilgore and Taylor believe that Indian fires were responsible for the frequent intervals before 1875 and that fire scar incidence decreased in the late 1800's and early 1900's because Indian burning activity ceased in the early 1870's. Since 1900, understory vegetation and fuels have increased significantly in the absence of frequent, low-intensity fires.

METHODS--LITERATURE SEARCH/ANALYSIS

The historical literature contains numerous observations of fires. Some of these have been reported by modern researchers. To understand the complete context of these observations, I located the original source and recorded the observation in its entirety. I also reviewed diverse and obscure literature covering the activities of fur trappers, explorers, missionaries, government surveyors, military expeditions, naturalists, emigrants, tourists, miners, and early settlers. I then developed categories appropriate for ecological interpretations, such as ignition source, whether the fire was burning at the time the observation was recorded, and the relative size of the fire. Data from each reference was then recorded (Gruell in press). The reliability of early accounts was tested using four criteria developed by historians for evaluating statements (Forman and Russell 1983):

1. Firsthand or secondhand observation.

2. Purpose or possible bias of the statement.

3. Author's knowledge of the subject.

4. Context of statement.

With few exceptions, the early accounts referenced meet these basic criteria.

RESULTS AND DISCUSSION

Accounts of Indian Fires

My conclusions are based on 145 accounts of fires on burned landscape covering the period 1776-1900. Environments described in these sources range from plains to mountain coniferous forests. Lightning undoubtedly ignited some of these fires; however, with the exception of a report by Ayres (1901), I found no mention of lightning fires. Lightning has clearly been a worldwide ignition source for thousands of years (Komarek 1965). Although historical evidence of frequent lightning fires has been cited for the prairies south of Calgary, Canada (Nelson and England 1971), few historical eyewitness reports describe lightning ignitions in North America. Indians may have been blamed for some fires because of observer biases.

Research in the Northern Rockies has shown that the efficiency of lightning as an ignition source decreases tenfold from the forested mountains of western Idaho to the plains of central Montana (Fuquay, n.d.). Except for rare, dry lightning storms, the efficiency of lightning ignitions in nonforested regions of the Interior West is restricted because the lighter fuels found there are readily wetted by precipitation accompanying thunderstorms. Also, fire starts in fine fuels are likely to be extinguished by subsequent showers. Considering these tendencies, presettlement lightning fires in grasslands were probably infrequent. Available data suggest then, that in heavy use areas the number of Indian-caused fires exceeded those caused by lightning (Latham 1983).

Indian fires were prevalent because fire was important to many activities, including cooking, lighting, heating, hunting, food gathering, forage enhancement, warfare, communication, vegetation clearing, ceremonies, and entertainment (Barrett 1981; Cooper 1961; Lewis 1973; Loscheider 1975; Moore 1972; Pyne 1982; Reynolds 1959; Stewart 1963). Fire use apparently varied with tribal customs and regional conditions. Widely prevalent uses in some environments had little or no application elsewhere. For example, fire would not be used to facilitate gathering of oak acorns in the Northern Rockies.

Of the 145 accounts of historical fires in the Interior West that were documented, 41 percent were attributed to Indians, although in some instances the observer no doubt mistook the reason for Indian fires or mistakenly attributed lightning fires to Indians. Stewart (1963) points out:

> Often travelers saw fires but did not see how they were started and, of course, could not ask for motives of the individuals who ignited them.

Forty-three percent of the fires attributed to Indians were believed to have been set for signaling purposes. Until about 1865, travelers in the Interior West were familiar with the Indian practice of using fire to communicate between scattered bands. For example, Father Escalante observed the following while in northern Utah in 1776:

> smoke is the first and most common sign which in case of surprise, all the people of this part of America use. (Alter 1928)

Likewise, in western Montana Capt. Meriwether Lewis (in 1805) and W. A. Ferris (in 1831) noted that Indians customarily set fire to vegetation to signal other bands (Thwaites 1959; Phillips 1940). In western Nevada in 1844, Capt. John C. Fremont reported the widespread use of fire by Indians to communicate:

> Columns of smoke rose over the country at scattered intervals--signals by which the Indians here, as elsewhere, communicate to each other that enemies are in the country. It is a signal of ancient and very universal application among barbarians. (Fremont 1887)

Of 25 reports on communication fires, 16 were convinced that signaling was the cause. While approaching Independence Valley in northern Nevada in 1829, Peter Skene Ogden observed:

> it is very evident from the numbers of fires in all directions that we are discovered by the natives. (Williams 1971)

About 2 weeks later in the Santa Rosa Range to the west, Ogden wrote:

> Fires were seen in almost every direction in the mountains, this is a convincing proof the natives are aware of our being here.... (Williams 1971)

Others made similar observations in various regions of the Interior West (Maloney 1945; Thwaites 1966b; Kelly 1930; Raynolds 1868), although not all were as certain about the fires' origins.

Firsthand accounts of Indians using fire for signaling are rare because few Indians traveled in the company of Euroamericans. Lewis and Clark and W. A. Ferris did travel with Indians, however, and both observed Indians setting signal fires (Thwaites 1959; Phillips 1940).

No mention of Indian signal fires was found in the literature after 1865. Marked changes in tribal distribution, intercommunication with Euroamericans, and relocation to reservations ultimately ended the practice.

Early observers also recorded reasons other than communication for Indian fires. These uses, for example food gathering and hunting, were undoubtedly more prevalent than the literature suggests (Davies 1961; Egan 1917; Oregon Historical Society 1901).

John Wesley Powell attributed widespread burning by Indians in the mountains of Utah to their systematic use of fire to drive game (Stegner 1962). He said this practice was a fact well known to all mountaineers. He did not mention the kind of game hunted or methods of applying fire.

Indian fires were set to enhance grass cover for horse forage. Peter Townsend noted the following on August 6, 1833, on Wood River below present day Ketchum, Idaho:

> on the main prairie scarcely a blade of grass could be found, it having lately been fired by the indians to improve the crops of next year. (Thwaites 1966a)

In August 1834, Captain Bonneville encountered the plains and valleys in the Powder and Grand Ronde drainages of southeastern Oregon "wrapped in one vast conflagration." This region was occupied by the Nez Perce tribe who ran large numbers of horses. Compiler Washington Irving suggests frequency and cause of this kind of burning:

> In a word, it was the season of setting fires to the prairies. (Todd 1961)

Indian fires in eastern Oregon and along the northern side of the Snake River in Idaho coincided with annual treks to the buffalo. On July 14, 1827, west of present-day Vale, Oreg., Peter Skene Ogden wrote:

> The country on all sides is on fire, these are signals for Indians to assemble as they shortly will steer their course to Buffaloe. (Davies 1961)

Other observers also commented on the Indian practice of setting fire to vegetation on their way to hunt buffalo (Fremont 1887; Thompson and Thompson 1982; Young 1899).

The experiences of Denig from 1833 to 1855, and of Havard in 1877, suggest that extensive prairie fires were an annual event in central and eastern Montana (Ewers 1961; Havard 1878). These fires occurred in the spring after the grass had been dried by Chinook winds and in the summer and fall as well. Indians set many of them.

Following his 1851 experiences on the Missouri River, artist Rudolph Kurz wrote:

> The only service the Indians render for the benefit of the herds is to burn the dried grass every spring in order that the young crop will be more abundant. (Hewitt 1969)

The purpose of these fires was to attract buffalo.

Indians also used fire to prepare seed beds for planting. Maximilian, Prince of Wied, observed in 1833:

> The Blackfeet like most tribes of the Upper Missouri, sow the seeds of the *Nicotiana quadrivalvis* having first burnt the place where they intend it to grow. (Thwaites 1966c).

Indians frequently used fire against enemies. In October 1826, south of present-day Bend, Oreg., Ogden's trapping brigade was nearly overrun by a wind-driven fire set by Indians (Davies 1961). Osborne Russell's trapping party escaped an Indian-set fire in September 1835 on the Madison River (Haines 1965). Granville Stuart observed fires set by war parties of Bannocks near Gold Creek on the Clark Fork River in western Montana in July 1861 (Phillips 1957).

Indian fires almost certainly increased in some regions soon after Euroamericans arrived. After acquiring the horse in about 1730, Indians were more mobile; thus the likelihood of ignitions increased in regions that were formerly remote. In areas of traditional occupancy, however, fire history and sediment core analysis show that short fire intervals persisted from at least A.D. 1500 to about 1860 (Barrett and Arno 1982; Smith 1983). Thus it appears that fire frequency increased in some regions after Indians acquired the horse, although in areas of uninterrupted occupancy over hundreds of years, the frequency of Indian fires did not noticeably change.

Season of Fire Occurrence

To determine the season when these fires most frequently occurred, I used data from a previous study (Gruell in press). Of 90 fires reported by early journalists (for which dates were given), 13 percent occurred in the spring (March to June). Most of these were attributed to signaling by Indians. A majority (79 percent) occurred during the summer and fall. Eight percent of the fires were recorded after September 30. Some of these post-September 30 accounts may have been ignited in late summer or in September. These data demonstrate that most early fires occurred during hot, dry weather after fine fuels had cured; the same pattern prevails today.

Extent of Indian Fires

Forty-four observers left 145 separate descriptions of early fires on landscapes of the Interior West. These accounts suggest that wildfires were widespread and often large (Gruell in press). During extreme conditions, some of these fires burned for extended periods (Thompson and Thompson 1982; Todd 1961; Young 1899). It is not possible to say precisely how many of the fires were set by Indians or how much landscape was affected by their fires. Nevertheless, through inference, the Indians' contributions seem to have exceeded that of lightning in the prairies, valleys, and lower elevation montane forests. First, Indians had many reasons for starting fires; second, fine fuels were widely distributed; and finally, the semiarid climate favored ignition and rapid combustion, particularly in late summer and fall. John Wesley Powell, leader of the U.S.G.S. surveys that included Utah, perceived the situation in the 1870's as:

> The protection of the forests of the entire arid Region of the United States is reduced to one single problem--Can these forests be saved from fire?

Powell later concluded:

> Everywhere throughout the Rocky Mountain Region the explorer away from the beaten paths of civilization meets with great areas of dead forests...in seasons of great drought the mountaineer sees the heavens filled with clouds of smoke. In the main these fires are set by Indians. (Stegner 1962)

The U.S. Geological Survey reports covering the Northern Rockies also recognized the past role of the Indians in setting fires. Leiberg (1904) concluded that Indian fires formerly had a major influence on forests and park lands in the Little Belt Mountains of west-central Montana. During this 1899 survey of forest conditions on the Lewis and Clark Forest Preserve in western Montana, H. B. Ayres noted that Indian-set fires were particularly evident in areas that were frequently traveled (Ayes 1901).

SUMMARY AND CONCLUSIONS

Historical records suggest that Indian fires significantly influenced vegetation in the Interior West before settlement by Europeans. Indians started fires for various reasons. The evidence suggests that fire occurrence varied greatly, depending upon the level of Indian occupancy, climate, and fuels. Indian fires were most frequent and extensive in the major grassland valleys and plains, where fuels were continuous. Major travel routes and occupancy areas supporting ponderosa pine also burned frequently. Fire size varied, depending upon fuels, weather, and topography. During extreme conditions, some fires burned for extended periods. Isolated mountain ranges such as those in central and southwestern Montana were particularly susceptible to Indian fires that swept in from the surrounding grasslands.

Indian fires were apparently common in the grass-covered mountains and higher valleys of many areas in the Interior West. Fires in such regions of continuous fuels were very large during extremely dry years. These fires carried into higher elevations in regions such as the Rocky Mountain Front and mountains of southeastern Idaho.

Indian fires in the upper-elevation Douglas-fir, subalpine fir, and lodgepole pine forests were apparently not common except in local summer habitation zones or along travel routes. In some areas, Indian fires may have commonly spread into lodgepole pine forests from the lower elevations. Indian ignitions may have also caused infrequent fires in more moist subalpine fir forests along travel routes or in localities preferred by hunters. These fires were probably small, except during weather extremes where fuels were continuous.

Knowledge of fire frequency is fundamental to interpreting the historical effects of fire on vegetation. Knowing that Indian ignitions were a primary source of fires in semiarid regions, one can understand why grasses predominated over woody vegetation during presettlement times as indicated by retakes of historical photographs.

The prevalence of Indian fires in the past helps explain the remarkable successional advances made by woody vegetation following Euroamerican settlement. Relocating Indians to reservations removed a principal cause of fires. This action, combined with the fine fuel reduction caused by domestic livestock grazing and efficient fire suppression, allowed vegetation to make marked successional advances.

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WHY INDIANS BURNED: SPECIFIC VERSUS GENERAL REASONS

Henry T. Lewis

ABSTRACT: Native North Americans once burned a variety of habitats for reasons related to strategies of hunting and gathering. Whereas "why questions" are useful for organizing historical materials concerning Indian practices, the knowledge older Native people in the boreal forest region of western Canada have about the dynamic relationships between fire and natural environments is ecologically much more significant and interesting than the several reasons that they may have had for setting fires. The general factors involved with setting habitat fires in some areas and excluding human-ignited fire from others were to enhance and maintain an overall fire mosaic: a complex, more productive, and stable environment than what derived from natural fires. In this respect, the fires set by hunter-gatherers differ from natural fires in terms of seasonality, frequency, intensity, and ignition patterns. Whereas the ecological knowledge of hunter-gatherers' uses of fire is now limited to older people in only the most remote regions of this continent, functionally similar situations to what existed in the last century can still be found in the northern part of Australia. Examples are described for two national parks in the Northern Territory where Australian Aborigines still use fire to influence the distribution and relative abundance of the animals and plants they still hunt and gather.

The most frequently asked question on the pyrotechniques of hunting-gathering peoples is: "Why do (or did) they set fires?" My research on traditional burning practices first involved historical reconstruction of Indian fire patterns in California (Lewis 1973); subsequently, it concerned recent fire uses by Indians in northern Alberta (Lewis 1977, 1980, 1982b); and most recently, the patterns of habitat burning that are still employed by Aborigines in northern Australia (Lewis 1982a, 1983). Whereas why questions serve well enough for organizing historical data, they are inadequate for interviewing people who carry out (or in recent times carried out) habitat burning.

This form of questioning is essentially limited because it does not lead our inquiry to understanding a people's perceptions of the consequences that different types of fire have for different kinds of habitats. Asking a hunter his reason for burning is analogous to asking a farmer why he plows: an informant having told you that he burned to improve an area for game (or perhaps one of another half-dozen reasons) is not then going to contribute much, if anything, about his overall knowledge of prescribed burning, any more than a farmer would automatically volunteer unsolicited information on his knowledge of cultivation.

At the crudest level a why question assumes that there was _a_ reason that people burned and that this involved folk perceptions of a simple cause-and-effect relationship. At a more sophisticated level, for people who are aware that hunters and gatherers fired a variety of habitat types in a given region, there is the recognition that there were a number of reasons, perhaps as many reasons as there were habitats or resources that are "positively" affected by one kind of a fire or another. Still, even at this level of understanding, there remains the assumption of one-to-one causal relationships between setting fires and achieving desired goals. In contrast, a person's perception of the complex causes and effects relating to fire are ecologically much more interesting than the one or more reasons that he or she may give for setting a particular fire.

From the adaptive arrangements of Eskimos in the arctic regions of northern Canada to those of Aborigines in the deserts of central Australia, anthropological research has shown that hunting-gathering adaptations involve extensive and detailed understandings of natural phenomena. Hunting-gathering peoples simply could not have subsisted had they possessed only a rudimentary knowledge of the world around them. If we think of _technology as knowledge_--knowledge which is used for practical purposes and not merely the tools involved--we can appreciate that there is much more to a hunting-gathering technology than the material culture of digging sticks, baskets, bows, arrows, and boomerangs. To successfully forage for plants and animals, people must understand the seasonal availability and regional distribution of the plant species used by them as well as those consumed by the animals they hunt. They must also understand the life histories and adaptive strategies of the resource animals hunted and the predators with which they compete. Thus, for a people to depend upon a few, mechanically simple tools to obtain a livelihood, they must have a broadly based and detailed knowledge of the environments they exploit --almost, it would seem, as a counterbalance to the limitations of their material culture.

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In this respect, a technology of fire involves much more than the fire drills, flint and steel strike-a-lights, and matches used to produce fire. With the exception of those societies found in arctic and in some equatorial forest regions, fires were a significant and integral part of human-environmental relationships for hunting-gathering peoples. Though my own work and that of others has singled out fire from the rest of the technological knowledge, it must be emphasized that habitat burning was but one component in the total system of a foraging adaptation.

For instance, we can similarly isolate and study the techniques of fishing or trapping, but the logic of individual activities cannot be fully appreciated unless considered within the overall context of hunting-gathering patterns. Obviously, of all the technological practices employed by hunter-gathers, none has as great an environmental impact as the prescribed uses of fire. The native peoples that I have interviewed in Canada and Australia are cognizant of a wide range of effects, desirable and undesirable, and for people to ignore or be indifferent to fire is considered by them to be foolish in the extreme. The contrast in advantages and disadvantages that fire can have was plainly stated by an Aborigine in northern Australia with the comment:

> That fella, fire, he been your best friend or he give you one helluva bad time.

It is unfortunate that our appreciation of the meaning and significance of traditional fire uses has come so late. Though Omer C. Stewart (1954) argued its importance 30 years ago, anthropologists and others have only undertaken the serious study of indigenous burning practices for little more than a decade. This belated interest emerged following developments in the field of fire ecology with anthropologists gradually recognizing that fires have important consequences for human adaptations beyond those of heat and light or for driving game.

As the earlier ethnographic record shows, anthropologists did occasionally note examples of habitat burning, but these observers had little or no ecological understanding of what was involved. For instance, a slightly apocryphal story related to me was that when asked if the Bushmen of the Kalahari Desert used fire, an anthropologist, with considerable experience in the region, replied:

> Well, yes, but they just set fires as they went along; I don't think that they thought much about it. But, of course, what am I saying? I didn't ask them about it either.

Because anthropologists did not know enough about fire ecology to "ask them about it" or to enter into discussions with people concerning their perceptions of cause-effect relationships, we have only passing references to and limited descriptions of what was more widely practiced throughout the first half of this century. Thus, the unfortunate part of our newly gained interests and insights is that we have acquired them just as the conditions for obtaining this type of knowledge are on the verge of disappearing.

However, despite there being only a few detailed studies from North America and Australia, we are able to generalize about hunting-gathering peoples' use of fire as a result of cross-cultural similarities, coupled with our knowledge of the fire ecology of specific habitat types. From these comparisons it is possible to at least reconstruct the outlines of the practices employed by indigenous peoples in affecting the environments that Europeans found on arrival in the New World and Australia. My aim here is to provide an overview of the general considerations that underlie hunting-gathering peoples' uses of fire. It is at this level that I will deal with the question of "why Indians burned."

In an earlier work (Lewis 1982a), which compared indigenous North American and Australian burning practices, I pointed out that there are four general considerations used by hunter-gathers that distinguish their fire regimes from natural ones: the seasonality of burning, the frequency with which fires are set, the intensity of fires, and the selection of preferred sites. These parallel considerations are shown for North American Indians across a wide range of habitats, as they are also for Australian Aboriginal groups in equally varied circumstances. The basic considerations that hunting-gathering peoples share with respect to the timing, repetition, intensity, and distribution of fires are key elements for understanding the more generalized reasons of why Indians and technologically like peoples set habitat fires.

As evidenced from the better-reported examples of burning that we have from western Canada (Arthur 1975; Lewis 1982b) and from the Pacific Coast States (Bean and Lawton 1973; Johannessen and others 1971; Lewis 1973; Timbrook and others 1984), the seasonality of burning varied from early spring to late summer to late fall, depending upon the resources sought and the habitats involved. Among Indians of northern Alberta, except for a few fires set in late autumn, all burning took place in the first 2 weeks of spring. Informants were unanimously agreed that the period of summer lightning fires, late July through August, was a most dangerous time for burning.

Among the Indians of Oregon and California, however, prairie fires (though not the brush or the forest understory fires also set by them at higher elevations) were ignited in late summer and early fall. As reported by Johannessen and others (1971), the potential hazards of fires at this time were offset by the fact that Indians burned prairies on a yearly basis, thus producing low-intensity fires that were restricted to selected habitats.

In the Canadian Great Plains the short-grass prairies were burned each autumn following the tribal bison hunts. Arthur (1975) reports that

this pattern of burning, often extending over hundreds of miles in a single conflagration and scorching almost all of the open prairie grasslands each year, forced bison into the surrounding tall-grass prairies of parklands and mountains, where Indians hunted them during the winter. With the onset of spring, bison were attracted to the new growth of grasses on the plains while behind them the parkland prairies were fired.

In many respects the Plains Indian way of life, a historically recent development that followed the introduction of the horse and gun, was an exception. In its preoccupation with bison, it more closely followed a nomadic, pastoral pattern of resource exploitation. Elsewhere in North America, Indians exploited a greater diversity of resources and, correspondingly, a wider variety of habitat types. It is in the management of such a broad resource base and a diversity of habitats that the general, most fundamental reasons for Indian burning practices are evident. The Indians of northern Alberta, people that I am most familiar with, provide a good example of the interdependence between resource exploitation and burning patterns.

The boreal forest supported relatively small populations of Indian hunters and gatherers. In comparison to temperate forest regions, resources are more widely distributed and fewer in number. In historical times, northern Indians expanded their traditional resource base by including within it the trapping of fur-bearing species and the trade goods that they obtained in exchange. This did not involve any fundamental change in human-environmental relationships, only the emphasis put upon burning to affect the relative abundance of this or that species. For example, in the 19th century, there was a shift from a greater dependence upon caribou, a late succession species, to a dependence upon moose, an early succession species; with this came an increase in the reported amount of Indian burning (Knight 1965).

Within the boreal forest region, burning entailed the maintenance of grassland habitats, with small prairies, meadows, and sloughs making up some 2 to 5 percent of the region. Except for firing windfalls of dead and downed trees, efforts were made to exclude fires from forest stands, this being largely accomplished by burning grasslands while surrounding forests remained too moisture laden to ignite. With the exception of some isolated stands of white spruce and pine, the combination of human-ignited and lightning fires probably enabled most of the boreal forest region to burn at least once every 100 years (Hellum 1983). In the Rocky Mountain foothills the average age of stands is reported as only 67 years (Day 1972). At any point in time there was a complex mix of uneven-aged habitat types. It is this fire mosaic that provided the range and balance of resources for northern hunting-gathering-trapping adaptations.

The Indians of northern Alberta are well aware that a diversity of habitats is important for maintaining a range of resources. They are also cognizant of the interrelationships, particularly as they involve animals, between different habitat types as well as the characteristics of habitats at different stages of succession. There is, certainly, an awareness of an interrelationship of parts, what we would call a system, and they fully understand the role of fire for alternately changing and maintaining a variety of plant communities at variable stages of maturity. At the same time, informants maintain that the mix of habitat types in northern Alberta has changed in the past 50 years and that once more diverse environments are now dominated by brush and trees and are less productive of preferred resources.

There is also a recognition that this diversity of habitats offers greater security and stability: secure because there is a greater variety of resources and because it is potentially less dangerous for patterns of human occupation and exploitation; stable because there are fewer major disruptions. Whereas summer lightning fires have always been a condition of the northern forest environment, Indians state that fires today are far more disruptive and potentially much more dangerous because of the buildup of fuels and, they maintain, this is largely a consequence of the restrictions made against traditional burning practices. Perturbations are accepted by them as a natural condition of life but, they add, the scale of disruptions was formerly reduced by their continued and regular use of low-intensity spring fires.

As one dimension of stability there is the understanding that it is easier to plan for and predict events relating to the location and relative abundance of resources, as well as the protection of resources and people. This is possible because the act of intervening with human-ignited fires helps reduce the irregularities in occurrence, distribution, and impact deriving from natural conflagrations. There is also a clear recognition of the importance of edges, or ecotones. As a part of the overall diversity or mosaic, edges between grasslands and forests are recognized as ongoing effects of fires and are places frequented by herbivores and, in turn, predators.

Whereas I have never had an informant answer the question of why fires were set by detailing the importance of mosaics, resource diversity, environmental stability, predictability, or the maintenance of ecotones, elements of these ideas were regularly presented and, in response to additional questions, discussed knowledgeably. The Indians of northern Alberta do have a "theory" of what they do; that is, they do perceive a network, a system of causes and effects. Their actions with respect to burning are not based on some kind of mindless, habitual practice. An adaptation so highly dependent upon the distribution and relative abundance of plants and animals required that they think in systemic, relational terms about the environment. Other studies of boreal forest adaptations fully support the interpretation that Indians held a systemic view of natural phenomena (Brody 1981; Feit 1973, 1978).

Similar contrasts to the regionally variable patterns of Indian burning are evidenced for a variety of environments in regions of Australia (Lewis 1982a:59-63). By way of comparison with hunter-gatherers outside of North America, I would like to conclude my examples with one that I have recently become familiar with from northern Australia. Two general types of burning are employed in Australia. Hunter-gatherers burn in one fashion and cattle pastoralists burn in another fashion.

Despite the fact that Aboriginal life-styles have been greatly altered, even in the most remote regions of northern Australia, some aspects of traditional subsistence relationships still remain, and among them are patterns of burning grasslands and forests. Though practices are now more limited than in the past, especially in the absence of a more nomadic way of life, fires are still set throughout Aboriginal reserves and on government lands in the Northern Territory, Queensland, and Western Australia, especially in northern Arnhemland and on Cape York Peninsula. Today groups of individuals can be found living in the bush for several months of the year and partially dependent upon traditional foods or "bush tucker." As a part of this adaptation around what are called "outstations," Aborigines continue to use habitat fires to maintain a range of plant and animal resources. The dynamics of this more-or-less traditional fire regime have been described in detail by Haynes (1982, 1983) and its place within a hunting-gathering strategy by Jones (1980).

Lightning fires are rare events in the northern Australian savanna region, largely because the frequency and wide distribution of human-ignited fires preclude the buildup of fuels. Lightning storms precede the onset of the wet season in mid- to late December and are shortly followed by monsoon rains that last through March. Cooler, drier weather begins in late May or early June, at which time fires are set by both Aborigines and pastoralists. By mid- or late July pastoral firing is nearly complete, whereas Aboriginal burning continues in selected habitats for weeks or even months longer. By late September or early October, however, Aboriginal fires are no longer being set.

Aborigines begin by burning the grassland margins adjacent to stands of monsoon forest, places that they wish to safeguard when the nearby flood plains or tall open forests are fired later in the dry season. Understory grasses and shrubs of the tall open forests are fired in a patchy manner from June through August, whereas fires in the eucalypt woodlands are generally larger and may be set as late as mid-October. Cattlemen, on the other hand, do not burn the flood plains, but they do burn much larger portions of the tall open forest and eucalypt woodland areas. Most fires set by pastoralists occur between mid-May and mid-July and are set as an aid to mustering cattle (the tall stands of sorghum grasses make transit difficult) and, more importantly, to induce an early, palatable growth of "green pick." If breaks occur during the wet season (in January or February), pastoralists, unlike Aborigines, may set fires to retard the seeding of native grasses and encourage the introduction of exotic species.

Aboriginal fires are relatively small and the areas covered are irregular from season to season; within stands of tall open forest, fires may be as small as a hectare or as large as 30 or more hectares. In the drier eucalypt woodlands, areas less important to Aborigines, fires may cover 62 sq. miles (100 sq. km) or more, especially if there have been long intervals between fires and the burning occurs late in the season. The total area burned by Aborigines within tall open forest stands (30 to 40 percent) is less than that burned by stockmen (60 to 90 percent), but the Aborigines burn over a longer period of time. Pastoralists attempt to burn in the shortest period of time and over the widest possible area, and today this is facilitated by aerial ignitions and other mechanical means. The sites burned by Aborigines are associated with camping, walking, hunting, and gathering areas. In contrast, pastoralists begin by burning the higher ridges and work down into lower-lying areas as soon as drier conditions permit. Aboriginal fires are set along corridors of movement and occupation, are associated with a wide range of human activities, and are set so as to influence a large number of species. Pastoral fires, except those set to guard buildings and corrals, are set more widely so as to manage the distribution and numbers of a single animal species.

The major difference between the two patterns of burning concerns the resources involved: grass and cattle for stockmen; numerous plant and animal species for hunter-gatherers. The stockman pattern entails an emphasis on greater uniformity; the traditional Aboriginal pattern, greater diversity. Each fire regime is geared to and is a part of a particular resource strategy; each is rational in that context. According to several studies, the stockman's aim of creating a more productive habitat for cattle by increasing the amounts of grass is partially achieved in that regrowth of woody species is reduced. This is partly because of the burning and partly because of the effects of grazing (Norman 1963, 1969; Tothill 1971a, 1971b). By comparison, the Aboriginal pattern intensifies the environmental mosaic. The hunting-gathering fire regime is not specifically suited to the needs of pastoralism in northern Australia, although the changeover from it to the pastoral pattern in most areas was accomplished with little more than a shift in emphasis. This shift, within which Aboriginal cowboys played a major role, was summed up by a retired cattle station manager in saying:

> For Abos [Aborigines] the change from burning and hunting for roos [kangaroos] to hunting and burning for cattle was easy. It just meant that they had to deal with one animal instead of a hundred-and-one other damn things.

Aboriginal burning practices are now being replicated in two national parks in the Northern Territory: Kakadu and Cobourg Peninsula. In both areas, fire management involves park personnel (many of whom are Aborigines) and the traditional Aboriginal landowners who continue to use fire as part of their ongoing hunting and gathering activities in coastal and inland habitats. In terms of environmental management and the participation of indigenous peoples, there is nothing quite like this in North American parks and wilderness areas. With the exception of the Canadian north and Alaska, there are few parks where Native peoples could be involved in similar ways or where former residents would still have a knowledge of, much less be allowed to apply, such practices. For most regions of North America, indigenous burning practices can only be based on limited historic and ethnographic references plus our knowledge of fire ecology.

It is here that anthropologists, specifically those studying fire technologies and hunting-gathering adaptations, can perhaps provide encouragement and suggest caution. If current goals are to reestablish areas as they existed at the time of contact, the examples provided by historically recent hunting-gathering adaptations can provide examples and broad outlines of fire management that were designed for maintaining the diversity and productivity that were important to hunting-gathering strategies. Even in the absence of locally detailed historic or ethnographic descriptions, on the basis of ethnographic comparison and a knowledge of the plants and animals exploited it would be possible for researchers to recreate at least the general outlines of the fire techniques employed at the time of European contact.

The words of caution have to do with the fact that, as hunter-gatherers, Indians did, of course, harvest large numbers of the plants and animals that they influenced with burning. It was, after all, a hunting-gathering management program, not a fire management program, and the use of Indian fire technology, separate and apart from the rest of a hunting-gathering adaptation, could conceivably present problems for managing parks and wilderness areas. Similar problems with uncontrolled elk populations have been reported for Sweden (Bergstrom 1982; Lavsund 1981; Persson 1982; Sandberg 1982), and like situations might also emerge if the larger hunting and gathering contexts of traditional burning techniques were ignored.

Whatever the case, Indian examples of habitat burning can be used as guidelines for controlled burning which, like any guidelines, may be acted upon to greater or less degree. In this respect those anthropologists with appropriate backgrounds can make a contribution to fire management programs within parks and wilderness areas by providing information on indigenous fire regimes and the overall systems of hunting and gathering.

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245 ECOLOGICAL EFFECTS AND MANAGEMENT IMPLICATIONS OF INDIAN FIRES

Stephen F. Arno

ABSTRACT: Current evidence suggests that Indian fires substantially augmented those set by lightning in grassland, shrubland, and certain lower-elevation forest types for a millennium before settlement by Euro-Americans. In some large areas Indian fires apparently had a marked and continuing influence on vegetation. Managers of wilderness and other natural areas should assess the probable effects of past Indian fires on their ecosystems and consider this information in developing management alternatives.

INTRODUCTION

Previous papers (Gruell; Lewis this proceedings) indicate that fires started by American Indians were common in what is now the central and western United States and adjacent portion of Canada. In this paper I present my hypotheses concerning the effects of Indian fires on major vegetation types from the Great Plains to the Pacific Coast and discuss the implications for fire management in wilderness and natural areas.

TIME SPAN OF INDIAN FIRES

Indian fires evidently had a widespread influence on vegetation in much of central and western North America until the mid-1800's (Stewart 1956; Moore 1972; Lewis 1973, 1982; Pyne 1982; Gruell 1985, this proceedings). Aboriginal ignitions augmented lightning ignitions and thus shortened the average intervals between fires in many of the grassland, shrubland, and dry forest types.

It is difficult to determine when extensive Indian burning first began and thus how long it continued, but evidence from several areas suggests that Indian fires were common for a rather long period before Euro-American settlers arrived. In western Montana, investigations of fire-scarred trees suggest that aboriginal burning extended back at least to A.D. 1500, whereas Euro-American settlement began in about 1860 (Barrett 1981; Barrett and Arno 1982).

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Palynological studies in a ponderosa pine/Douglas-fir (*Pinus ponderosa/Pseudotsuga menziesii*) forest near Lewiston in northern Idaho suggest that frequent Indian fires may have begun about a millennium ago (Smith 1983). Similarly, investigations of sediments in two western Montana bogs show a large increase in wind-deposited charcoal beginning between 1,000 and 2,000 years ago (Mehringer and others 1977; Hemphill 1983). Indian fires may have been responsible for this charcoal deposition because no related major change in climate was evident. Anthropologists queried by Kilgore and Taylor (1979) felt that Indian burning may have occurred for roughly a thousand years in the ponderosa pine-mixed conifer forest of the California Sierra Nevada. Fritz (1931) found that a history of frequent fires extended back at least 1,100 years in an area of the California redwood (*Sequoia sempervirens*) forest. Indians were implicated as a major ignition source (Thompson 1916; Lewis 1973; Veirs 1982) because lightning fires are uncommon in that area.

ECOLOGICAL EFFECTS

I will present my hypotheses about the effects of Indian fires by major vegetation zones (Küchler 1964).

Grasslands and Sagebrush

Prior to Euroamerican settlement, native grasslands covered most of the Great Plains from northern Texas to southern Canada. Grasslands also dominated extensive areas of Washington and Oregon's Columbia River Basin, California's Central Valley, and smaller areas of the West's drier intermountain valleys. In general, frequent light fires help perennial grasses to maintain dominance because they regenerate readily from buds near the soil surface. Less frequent burning allows fire-tolerant, resprouting shrubs and trees to develop; these include chokecherry (*Prunus virginiana*), serviceberry (*Amelanchier*), and aspen (*Populus tremuloides*). Long intervals between fires favor development of nonsprouting shrubs, such as big sagebrush (*Artemisia tridentata*), and most coniferous trees.

Evidently Indians set many fires inadvertently and for several purposes in the grasslands. Indian

fires may have equaled or exceeded lightning fires in numbers (Moore 1972; Gruell 1985), and the short intervals between all fires favored expansion of grasslands into the adjacent shrub or tree "habitat types" (potential climax without fire) (Gruell 1983). Shrub and tree communities have now developed in some former grasslands as a result of fire suppression and grazing. In northern California (Lewis 1973), western Oregon (Habeck 1961; Thilenius 1968; Johannessen and others 1971), and northern Alberta (Lewis 1980) seral grasslands were maintained by deliberate burning in environments that through vegetal succession would have developed into forest.

Sagebrush (*Artemisia* spp.)-grass communities cover a large part of the semiarid Intermountain West, from the east slope of California's Sierra Nevada to southeastern Wyoming. On the more productive sites--those that are relatively moist and have well-developed soils--sagebrush dominance often appears to have resulted from past grazing and fire suppression (Gruell 1984). Grassland may have dominated these areas until the late 1800's. By that time, however, heavy domestic grazing had reduced grass vigor, giving sagebrush the competitive advantage; heavy grazing also removed fine fuels and thus prevented fires from spreading. In contrast, before the introduction of livestock, fire was relatively frequent. Fires probably occurred every two or three decades (Houston 1973; Arno and Gruell 1983, 1984) in all but the rockiest and poorest sites with inherently sparse vegetation. Many of these fires were apparently ignited by Indians, and fire's effect was to favor grass relative to most kinds of sagebrush and bitterbrush (*Purshia tridentata*), mountain-mahogany (*Cercocarpus spp.*), and most other shrubs. Dry and stony sites that supported only sparse vegetation and fuels probably burned less often, and shrub dominance was thus maintained. Today, succession on some sagebrush-grass sites has advanced to dominance by juniper, interior Douglas-fir (*Pseudotsuga menziesii* var. *glauca*), or other conifers. This seems to be the result of fire suppression and domestic grazing (Burkhardt and Tisdale 1976; Dealy and others 1977; Young and Evans 1981; Arno and Gruell 1983).

Pinyon-Juniper

Pinyon and juniper woodland communities occupy many of the mountain slopes and high plateaus from central Oregon to western Texas. This vegetation type commonly replaces sagebrush-grass under somewhat more moist or cool conditions. Pinyon and juniper also represent the potential climax, in the absence of fire, on some sagebrush-grass sites (Wright and others 1979). This woodland type sometimes occurs in a mosaic pattern with sagebrush-grass, occupying the stoniest soils, where fires spread poorly and competition from grasses and shrubs is minimal.

Pinyons and junipers can survive light surface fires but are killed by wind-driven crown fires. Indian fires no doubt often spread into pinyon-juniper woodlands and also kept the trees from invading the adjacent sagebrush-grass communities. Little is known about presettlement fire frequencies in pinyon and juniper woodlands. It appears, however, that before the introduction of domestic livestock in the mid-1800's, fires may have occurred at 15- to 90-year intervals, maintaining open or patchy stands in areas where woodlands have since become very dense (Young and Evans 1981; Rogers 1982; Gruell 1984). Tree densities have increased in many areas and undergrowth is so sparse (as a result of shading as well as past grazing) that surface fuels do not support fire. Thus, these stands now can burn only under extreme conditions--hot dry weather and strong winds. This woodland type receives large numbers of lightning ignitions, and Indian use and travel through it was substantial, probably resulting in many fires in the past.

Chaparral And Oakbrush

These dense, tall shrub communities cover hot, dry mountain slopes in California, Arizona, New Mexico, Colorado, and Utah. This vegetation type occurs upslope from the grasslands and other lowland types that were often burned by Indian fires. Lightning ignitions are also common in chaparral and oakbrush. The California chaparral evidently experienced frequent stand-replacing fires (5- to 40-year intervals), and these maintained mosaics of plant communities that differed in composition, structure, and age (Minnich 1983). The Rocky Mountain oakbrush (*Quercus gambelii*) resprouts vigorously after fire, and it evidently burned every few decades in presettlement times.

Indian fires undoubtedly spread into these types (Lewis 1973; Aschmann 1977; Gruell 1985). Fire suppression has now permitted large areas of old, decadent chaparral and oakbrush to develop.

Interior Montane Forests

Ponderosa pine and interior Douglas-fir make up the driest forest zones in most of western North America, from southern British Columbia to South Dakota and western Texas. Frequent surface fires--at average intervals of 5 to 25 years in most areas (Martin 1982)--were characteristic where ponderosa pine was abundant. Interior Douglas-fir forests lacking ponderosa pine occur at moderately high elevations, often adjacent to sagebrush-grass valleys in the Rocky Mountains; fire intervals in these cooler, dry forests average between 25 and 60 years (Houston 1973; Arno and Gruell 1983, 1984).

Evidence cited in Cooper (1960), Lewis (1973), Kilgore and Taylor (1979), Barrett (1981), and Gruell (1985; this proceedings) suggests that Indian fires were common; their frequencies probably equaled or exceeded those of lightning fires in some of these forests. Frequent surface fires kept stands open and parklike, and numerous 19th century travelers remarked that it was easy

to ride horseback through them without a trail. Selective logging and fire suppression since about 1900 have favored development of dense stands in which more shade-tolerant species--Douglas-fir and true firs (*Abies* spp.)--are replacing ponderosa pine. In many of these stands, accumulations of living or dead fuels probably exceed the maximums achieved before 1900 (Davis and others 1980; Gruell and others 1982). Insect and disease damage also seems to be heightened by the dense, decadent stand conditions (Mitchell and Martin 1980; Arno and Brown 1983).

As a result of fire suppression, and perhaps grazing disturbance, interior Douglas-fir has expanded into the adjacent mountain grasslands (Parminter 1978; Arno and Gruell 1983, 1984; Gruell 1983). In some areas ponderosa pine has also expanded into grasslands (Progulske and Sowell 1974), but Douglas-fir invasion seems more widespread, probably because past fires were much more damaging to small Douglas-fir than to the fire-resistant pine.

Interior Subalpine Forests

High-elevation forests in the Rocky Mountains, the Sierra Nevada, and the inland slope of the Cascades generally are dominated by lodgepole pine (*Pinus contorta*), subalpine fir (*Abies lasiocarpa*) or red fir (*Abies magnifica*), and in many areas Engelmann spruce (*Picea engelmannii*). Most of these "cool" forests produce sufficient tree and undergrowth biomass to have burned at intervals averaging between 50 and 300 years. Some sites, however, have such low productivity and sparse fuels that they rarely support a spreading fire (Arno 1980; Martin 1982). Some productive sites, such as spruce basins, support adequate fuels but rarely burn because moist and cool conditions are so prevalent.

Lightning frequently occurs in these subalpine forests, and short warm-dry periods are also characteristic during most summers. Indians occasionally traveled through these habitats, and sometimes lit fires for route clearing or other purposes. In areas where subalpine forests occur directly above the major valleys, Indian fires no doubt spread upslope into them. Overall, however, it appears that lightning was the prevalent cause of fires in these forests simply because of their remoteness.

Maritime Forests

Forests of western hemlock (*Tsuga heterophylla*), western redcedar (*Thuja plicata*), and Sitka spruce (*Picea sitchensis*) occupy an extremely moist and temperate climatic zone along the Pacific Coast from northern California to southern Alaska. Coastal Douglas-fir (*P. menziesii* var. *menziesii*) is a prominent associate in these maritime forests south of Alaska, and redwood occupies the southern end of this strip, in California. Moist "inland-maritime" forests of western hemlock and western redcedar mixed with inland conifers occupy the western slope of the Rockies in southern British Columbia and northern Idaho and vicinity. Although annual precipitation is relatively high (>35 inches; [90 cm]) in all areas of these maritime forests, a summer drought becomes increasingly common southward from Canada.

Moderate-to-severe wildfires occurred at long intervals (averaging between 60 and 350 years) in most of these forests from southern British Columbia to northern California. In the coastal areas these fires resulted in establishment of seral, coastal Douglas-fir whereas in the inland-maritime zone fires favored establishment of western white pine (*Pinus monticola*), western larch (*Larix occidentalis*), lodgepole pine (*Pinus contorta* var. *latifolia*), and other seral species. Lightning is infrequent in the coastal forests but is common in the inland-maritime zone; however, moist fuels limit fire frequency in both regions. Indian ignitions no doubt occasionally caused spreading fires in coastal and inland-maritime forests, but their past importance is unknown. In certain localities Indian fires were common, as in the northern California rewood country (Lewis 1973; Veirs 1982; Rice this proceedings).

MANAGEMENT IMPLICATIONS

Managers of wilderness, national parks, and other natural areas might benefit from knowing the past role of Indian fires in each vegetation type. Such baseline information is necessary to understand cause and effect; it should aid a manager in predicting vegetative development under different fire regimes. If the manager's goal is to develop or maintain a certain vegetative type or complex, then information on frequency and effects of past fires can be used to develop management alternatives.

Information on Indian use of fire in a specific area can be obtained by (1) searching the technical literature (in anthropology, history, vegetation ecology, and palynology); (2) investigating historical accounts (Gruell 1984, 1985); (3) interviewing anthropologists; (4) investigating fire scar chronologies from areas of past Indian use; or (5) conducting palynological and sediment studies (Smith 1983).

Presumably managers will set specific goals for each vegetation type. Definition of such goals will be essential for determining where managers might want to mimic or simulate the effect of Indian fires. Kilgore (this proceedings) pointed out that the term "natural fire" may or may not include Indian fires, depending upon the management direction. For example, the management goal might be to maintain "the biotic associations . . . as nearly as possible in the the condition that prevailed when the area was first visited by white man," as was recommended for United States national parks by the Leopold Committee (1963). In this case, any substantial role played by aboriginal fires might need to be simulated through the use of prescribed fire.

On the other hand, the Wilderness Act of 1964 (Public Law 88-577) defines wilderness as an area managed to preserve "natural conditions and which (1) generally appears to have been affected primarily by the forces of nature, with the imprint of man's work substantially unnoticeable." Does "man's work" in this case include that of aboriginal man? If so, this passage suggests that if an area's vegetation had been substantially altered by Indian burning when it was first observed by Euroamericans, that condition would not be "natural" nor qualify for wilderness. Thus, the ponderosa pine-mixed conifer and giant sequoia (*Sequoiadendron giganteum*) forests of the Sierra Nevada might not qualify for wilderness because they reflect a history of aboriginal burning and probably would have had less pine and sequoia without aboriginal burning. The language of the Wilderness Act however, does not definitely indicate whether Indian burning is to be considered natural.

Regarding vegetation management in the U. S. Department of Agriculture, Forest Service's Research Natural Area system, the following statement appears (Forest Service Manual 4063.38, March 1979):

> The Station Director, with the approval of the Forest Supervisor, may authorize management practices, except within wildernesses, necessary to preserve the vegetation for which the research natural areas was [sic] created. These practices may include grazing, control of excessive animal populations, or prescribed burning. Only tried and reliable techniques will be used, and then only where the vegetative type would otherwise be lost without management. The criterion here is that the management practice must provide a closer approximation of the vegetation and the processes governing the vegetation than would be possible without management.

If, for example, Indian fires helped maintain seral stands of ponderosa pine or giant sequoia, prescribed fire could be used to simulate the aboriginal fires.

Thus current management directions are variable and nebulous regarding whether "natural fire" includes those set by aboriginals. Once this issue is resolved for each type of natural area, managers can determine whether to use scheduled ignitions as a a substitute for Indian fires.

The use of prescribed fire in wilderness and natural areas is also of concern to managers of nearby nonwilderness. For instance, use of prescribed fire in wilderness might, if successful, help reduce the threat of wildfires or keep buildups of insects or diseases from spreading into adjacent nonwilderness forests.

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THE RELEVANCE OF PAST INDIAN FIRES TO CURRENT FIRE MANAGEMENT PROGRAMS

Clinton B. Phillips

ABSTRACT: Knowledge of past Indian fires can help fire managers plan programs of fire management for wilderness areas. But the term "Indians" includes many races of people who used fire in different ways to achieve particular goals related to their subsistence and security. Their use of fire may or may not fit current fire management programs and could be detrimental.

INTRODUCTION

Uncertainty about the proper and safe use of fire is a common trait of many fire managers. To establish fire management programs for wilderness areas, fire managers need all the knowledge they can acquire about fire and its effects on wilderness ecosystems. One source of information is the history of how Indians used fire and the effects of their fires on the wilderness (Barrett and Arno 1982).

In seeking this information, however, fire managers are challenged by several questions that have no simple answers:

1. Who were the Indians?

2. How did they use fire?

3. What were the effects of their fires on wilderness ecosystems?

4. Are past Indian fires relevant to current programs of fire management?

Unfortunately, our knowledge of past Indian fires is derived from an imperfect record. Even today, archeologists, anthropologists, and historians do not always agree on the history of Indians in America. The discussion in this paper, therefore, represents diverse viewpoints and highlights the complexity of determining the relevance of past Indian fires to current fire management programs.

WHO WERE THE INDIANS?

The English word "Indian" is applied broadly to all aboriginal peoples who lived in North and South America and the West Indies when the Europeans started migrating to the Americas in the 16th century. That is like applying the word "trees" to the many varieties of conifers and hardwoods that were in the Americas at the same time. The inclusive term fails to distinguish among the many ethnic stocks who arrived in the Americas in a continual series of migrations that spanned several thousand years.

Although our predecessors divulge their history with reluctance, most archeologists agree that the Indians began to enter North America from Asia at least 15,000 years ago (White 1972). Some studies place the date at well before 30,000 years ago (Josephy 1961; Brennan 1959). Initially, the Indians were hunters and gatherers of whatever resources nature provided. They probably followed migrating herds of animals across the Bering Strait both between and during periods of glaciation. Very slowly, over the millenia, they spread southward and eastward across the Americas. Because individual tribes or bands were so mobile, their territories were neither recognized nor defended (Bettinger 1978). Their relationship to the land changed constantly, depending on the availability of needed resources, climatic changes, and forcible relocation by other Indians (Canby 1982; Bettinger 1977).

Tribal cultures were also constantly evolving. In time, perhaps 5,000 years ago, the mobile hunter-gatherer culture began to be replaced, at least in some tribes, by a more stable, agricultural way of life. Among the Indians who became agriculturists, some impressive civilizations developed. Permanent villages and systems of irrigation were constructed and land and resource use intensified (Bettinger 1982; Canby 1982; Rappaport 1972). Increasing evidence has emerged during the past decade which shows, beginning at least 4,000 years ago and continuing through the centuries to the time of Columbus' voyages, there were infusions of new, advanced cultures (Fell 1982; Fell 1980; Fell 1976). These new cultures were brought to the Americas by both permanent settlers and traders who traveled by boat across the Atlantic and the Pacific from Europe, Asia, Africa, and Polynesia. And, finally, there was the cultural influence of the later wave of Europeans who migrated to the Americas on a large scale following Columbus' voyages to the Americas. Many cultural traits that settlers observed in later years among the western Indians of North America had European origins; these traits had been transmitted previously by Europeans to tribes through east-to-west diffusion (Downs 1966).

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HOW DID THE INDIANS USE FIRE?

Despite their ethnic and cultural diversity, the many groups of Indians shared at least one cultural tool: they all used fire in one way or another (Pyne 1982; Stewart 1956). Except for written historical accounts of the past 200 or 300 years, however, it is difficult to know precisely how the Indians used fire and to what extent their economies depended on that use. Most archeological information is fragmentary at best (Barrett and Arno 1982; Agee 1974). Even the oral statements of living Indians are not always reliable because their perceptions of how their ancestors used fire may distort reality (Barrett 1980). The clouded vision of the past is made more obscure by the difficulty of separating the history of Indian fires from that of natural fires and fires ignited by early trappers, miners, herders, and some settlers (Alexander 1980; Mutch 1980; Arno 1976). Even the written accounts of early European travelers, trappers, and settlers are subject to different interpretations and conjectures about how the Indians used fire (Pyne 1982; Burcham 1974).

There is general agreement, however, that the Indians' use of fire varied significantly among different tribes (Pyne 1982; Downs 1966). Hunters and gatherers, for example, adapted to their changing environments and to available resources. If the environment and resources changed, so did the Indians' manipulative use of fire. As the hunters-gatherers evolved into or were replaced by more stable communities of agriculturists in some areas, the Indians' use of fire still varied considerably from ecosystem to ecosystem in seasonality, frequency, intensity, and scale (Lewis 1980; White 1972).

The sophistication the Indians employed in their use of fire also varied among tribes and was influenced mostly by tribal traditions and the natural availability of resources. In some areas, Indians seemed to ignite fires rather arbitrarily and unsystematically (Barrett 1980). As the veil of history slowly parts, however, there appears increasing evidence that many Indians were highly skilled in the use of fire. Lewis (1982), in his studies of Indians in northern Alberta, states:

> A reasonably convincing argument can be made that the Indian technology of burning is, or at least was at one time, well ahead of our own. [The Indians had] the perception of distinct microhabitats of plants and animals, used variously for human needs, involving complex internal and external relationships, which simultaneously distinguish and relate such communities. [This view] is a practical, time-tested understanding by humans who had come to know and successfully manipulated boreal forest systems for practical purposes.

He further asserts that because the Indians in northern Alberta understood how to control their fires, they were able to establish and maintain plant communities, and the animals found in them, at preferred stages of ecological succession. From less strong evidence of Indian fires in California, Lewis infers that at least some Indians in that area also understood how to employ and control fire seasonably and at particular intensities to achieve desired results (Lewis 1973; Burcham 1974).

How did the Indians use fire? Except for the recent past in a few local areas, the historical record cannot be read with great accuracy. That record only infers that Indians used fire in ways that we do not well understand to manipulate ecosystems so as to achieve their particular goals.

WHAT WERE THE EFFECTS OF INDIAN FIRES ON WILDERNESS ECOSYSTEMS:

Although we cannot establish how Indians used fire, it is important to attempt to understand the effects of their fires on wilderness ecosystems.

The geological record shows that fire-adapted ecosystems have persisted in the Americas since at least the Miocene Epoch of the Tertiary Period, some 13 million years ago (Burcham 1974). Fires due to natural causes, primarily lightning, significantly affected grasslands, tundra, chaparral, swamps and marshes, and forests throughout North America long before the Indians arrived some 15 to 30 thousand years ago (Pyne 1982; Vogl 1973). Nevertheless, as Pyne (1982) has described, the arrival of people and fire from Asia superimposed a new and extensive fire regime over an existing natural one in many parts of North America. Succeeding migrations of people from Asia, Africa, and Europe caused still more transformations in fire regimes. In combination with natural climatic shifts, evolving changes in the Indians' cultural use of fire caused fire regimes to be constantly in flux.

Because of these changes, it is difficult to sift the specific effects of Indian fires on fire regimes from the total mix of historical evidence. However, it seems apparent that Indian fires created and maintained vast expanses of grasslands and open stands of forests, primarily for ease in harvesting food resources (Lewis 1980; Burcham 1974). There is evidence that these grasslands were still expanding, usually at the expense of forests, when Europeans arrived in the 1600's (Pyne 1982).

High elevation wildlands in western North America probably received less impact from Indian fires than low elevation grasslands and forests (Lewis 1973). High elevation lands were generally remote from Indian communities and supported less food resources; therefore Indians had little reason to visit them. In addition, high elevations were more likely to experience fires of smaller size and lower intensity than lowlands because of discontinuous fuels and less severe fire weather.

The Book of James (3:5) includes a biblical admonition, "Just think how large a forest can be set on fire by a tiny flame!" Undoubtedly, the Indians learned that lesson because their fires were sometimes detrimental to their interests. Modern fire managers can readily relate to this situation. Indian fires occasionally altered major migration patterns of animals, interfered with nesting of birds, killed or injured bison, destroyed trees, and caused some plant species to become extinct (Nelson and England 1978; Ridpath 1971).

The Indians' fires often caused conflicts with the Europeans who came to North America after the 16th century. Settlers from northern Europe generally had limited experience with fire in the forests; they feared it and considered it hazardous (Barrett and Arno 1982). Well they might. Fires, frequently those set by Indians, sometimes killed their livestock, burned their crops and trees, and destroyed their settlements. The consequence was fire control legislation and the formation of fire protection districts in many parts of eastern North America (Nelson and England 1978). (It should be noted that English and Scotch settlers in some mountainous parts of the southeastern United States soon learned the use of fire from the Indians and applied it to clear land and improve forage for their livestock.) Settlers whose ethnic origins lay in southern Europe were more knowledgeable about fire and the damages its uncontrolled use could cause. Early Spanish and Mexican settlers in California, for example, had their livestock and pastures destroyed by Indian-set fires. Out of desperation, Governor Don Jose Joaquin de Arrillaga issued a proclamation in 1793 prohibiting the Indians from starting fires (Clar 1959). In later years, as industrial forestry moved westward across North America, the first difficulty encountered was usually wildfire, often set by Indians (Pyne 1982). Consequently, in the latter part of the 19th century and into the 20th century, public programs of fire protection evolved; they sought to prevent and quickly control all wildland fires. The pendulum of time had swung from the effects of natural fires on wilderness ecosystems to the added effects of Indian fires, and then back in the opposite direction to the consequences of efforts to suppress all wildfires.

And so we come to the present and the recognized need to take a fresh look at the role of fire in the wilderness, including the relevance of past Indian fires.

ARE PAST INDIAN FIRES RELEVANT TO CURRENT PROGRAMS OF FIRE MANAGEMENT IN WILDERNESS AREAS?

A definition of wilderness is critical to any discussion of fire management in wilderness areas. Wilderness is defined in the Federal Wilderness Act of 1964 (Public Law 88-557) as "untrammeled by man," "retaining its primeval character," "managed so as to preserve its natural conditions," and "affected primarily by the forces of nature." In my opinion those defining phrases mean that fires like those ignited in the past by Indians have no place in wilderness areas. Only fires caused by natural elements are appropriate.

The fire management policies of Federal agencies responsible for wilderness management further complicate the wilderness fire issue. Wilderness simply cannot be managed in isolation from other lands; adjacent land values and management plans and other external forces may significantly affect these areas.

By considering the context in which wilderness fires occur, each responsible Federal agency has developed a fire management policy for its wilderness areas (USDA Forest Service 1976; USDI Bureau of Land Management 1981; USDI Fish and Wildlife Service 1982; USDI National Park Service 1982). Excluding the Bureau of Indian Affairs, these policies have several common characteristics:

1. There must be an approved fire management plan for each management unit.

2. Natural fires may be allowed to spread under prescribed conditions.

3. Natural fires must be suppressed where they threaten values outside the wilderness area or when they are spreading outside of prescribed conditions.

Also the agencies have adopted or are working toward a fourth common policy: When natural fires do not or cannot be allowed to achieve "natural conditions," they may be supplemented by prescribed burns ignited and managed by qualified fire management personnel. Usually human-caused fires, other than prescribed burns, are to be suppressed. There are exceptions in some agencies.

The programs are relatively new. Consequently, the ultimate effects of the programs to restore and maintain natural wilderness ecosystems involves evaluation over a long time.

One important issue is the real meaning of "natural wilderness systems." As Pyne (1982) asserts:

> Wilderness is no longer simply a state of nature; rather, it is the interaction between a continually changing state of nature and a perpetually evolving state of mind. The program (of using natural fire) is less a case of restoring a natural phenomenon so that it may interact with its natural environment than of managing one cultural and natural hybrid, fire, in its interaction with another hybrid, wilderness.

Because most wilderness areas are not yet in a natural condition, whatever that may be, and because not all natural fires are allowed to burn, fire managers find it hard to plan and execute fire management programs. Among other things, they must look at fire history in an area to determine the natural role of fire. But they find that history difficult to interpret because of continual past changes in the fire environment and the overlapping effects of natural fires, Indian fires, and other

fires. Even if the obscure record is clarified and the effects of Indian fires are sifted from those of other fires, fire managers must use extreme care in translating the information into current fire management programs.

Archeological finds, biological studies of plant changes and successions, and oral and written historical accounts give strong evidence that most Indians used fire in the past throughout North America. Their use of fire certainly modified many natural ecosystems and were particularly instrumental in opening the forests and expanding grasslands.

But fire managers must recognize that precisely how the Indians used fire is not known too well in terms of techniques that might be applicable today. Also fire managers must remember that the Indians' objectives in using fire differed greatly from those of managers responsible for most of today's wilderness areas; that the conditions under which the Indians burned were entirely different from the environmental, social, and economic conditions that exist today; and that the effects which the Indians obtained with their fires could interfere with achieving today's objectives. If fire managers keep these precautions in mind, the history of Indian fires can still provide valuable knowledge needed to formulate current fire management programs for wilderness areas.

SUMMARY

From the shadowy mists of the past come the following observations about Indians and their use of fire:

1. The Indians were a mix of many different ethnic races and cultures, arriving from several continents and spreading slowly through the Americas during at least the past 15,000 years.

2. Apparently, the Indians' use of fire was almost universal. That use varied considerably, however, among tribes, over time, and among different wilderness ecosystems.

3. The Indians used fire to achieve their particular objectives, most of which were related to subsistence and security.

4. Because the Indians had little reason to visit the higher elevation wildlands, those lands received little impact from Indian fires.

5. The Indians' fires usually favored their existence, but sometimes damaged natural ecosystems.

6. When Europeans started migrating to the Americas in the early 1600's, Indian fires interfered with their land-use objectives and caused conflict between settlers and Indians.

7. The conditions under which the Indians burned in the past no longer exist; today's wilderness ecosystems are the result of a long and complex history of changes and evolution in the natural environment and in people's use of the land and its resources.

These observations have lead me to the following conclusion: Knowing how the Indians used fire in the past might help managers achieve current fire management objectives for some wilderness areas but not for others; it could even be detrimental. Past Indian fires are relevant only when the management objectives for a particular wilderness area specify that the area's ecosystem is to be like that which existed when Indians were the only human influence. Otherwise, information about past Indian fires becomes only a part of the total knowledge that fire managers must have in order to conceive and achieve fire management programs in support of today's land-management objectives.

Aldo Leopold offered advice that seems applicable to this issue (Gibbons 1981):

> We shall never achieve harmony with land, any more than we shall achieve justice or liberty for people. In these higher aspirations the important thing is not to achieve, but to strive....

Strive we must: to learn what we can about past Indian fires and to use the information where it is applicable.

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245 ECOLOGICAL IMPLICATIONS OF IGNITION SOURCES IN PARK AND WILDERNESS FIRE MANAGEMENT PROGRAMS

Don G. Despain

ABSTRACT: The large number of variables involved in the development of fire after ignition and its subsequent behavior makes the effect of ignition extremely variable and unpredictable. Our state of knowledge is such that prescribed[1] fire cannot be expected to mimic natural results. Opportunities to study fires uninfluenced by humans are essential if we are to understand the role this force plays in our ecosystem.

INTRODUCTION

Ignition sources of wanted fires fall into two categories. One category includes those fires deliberately started by humans for a specific purpose, usually to aid human beings in their struggle for existence (campfires, hunting fires, slash burns, brush control, etc.). These I will refer to as prescribed fires. Occasionally control of these fires is lost, and they do not fulfill the intended purpose (escaped or accidental fires). The other category includes ignitions by natural sources such as lightning. These I refer to as natural fires, fires uninfluenced by man (today most of these are immediately suppressed, but in some areas they can be allowed to burn). In some agencies these are also called prescribed fires because they meet the criteria that they must have a purpose. The difference is whether man or natural forces ignited the fire. These fires are expressions of the environment and are part of the forces that have shaped the systems from which we derive our sustenance. An obvious question comes to mind: Is there any difference between the two ecologically?

DISCUSSION

If we could run a controlled experiment in which all variables were constant except the ignition source, we would probably find no ecological difference between human-caused and naturally caused fires. Wilderness areas, however, are far from controlled experiments. Because conditions vary widely in both time and space, our present knowledge and technology, in my opinion, do not allow us to predict with assurance the outcome of an ignition in wildland conditions.

Observations during 10 years of allowing fire to play its natural role in Yellowstone National Park ecosystems have brought to light much previously unconsidered information. Several examples follow. Fires have occurred mainly in old growth stands. Yellowstone National Park forests are 56 percent old growth with a well-developed understory of tree reproduction, usually Engelmann spruce and subalpine fir. Approximately 80 percent of the 123 fire starts allowed to burn themselves out in the park have started in these old growth stands. Only 22 of the 123 fires burned more than 5 acres (2 ha), and 20 of those started in the old growth stands. Conventional wisdom would probably have suggested that most fires would occur in lodgepole pine stands, considering the common view regarding the relationship of fire and lodgepole pine.

It is also important to note that about 80 percent of the 123 fire starts never developed into forest fires. Conditions were not right for continued development. Apparently, large fires do not result from every ignition. We need to know more about the factors determining when a fire does develop. Fires are sensitive to weather conditions. Most fires in the park have ignited when 1,000-hour fuel (fuels larger than 3 inches [76 mm] in diameter) moisture has been below about 15 percent. This has been as early as July 12 or as late as August 10. Some years this level is never reached.

In Yellowstone National Park extreme fire behavior is the rule rather than the exception. During those 10 years, four fires burned a total of 27 acres (11 ha) as creeping surface fires or underburning. The rest of the fires burned as fast-moving crown fires and burned 33,124 acres (13 405 ha). In other systems with similar fuels and climate, fires did not crown. Considerable acreage can burn as surface fires or underburning without consuming or killing the crowns of the larger trees.

Fires can persist for long periods. If fires in the park are able to burn a few acres, they usually continue for a considerable time, commonly up to 8 or 10 weeks. Obviously, such fires are not active through most of their duration, and large acreage increases are only sporadic.

The effect of fire on the biotic community is very time-dependent. Plant phenology determines the state of a seed bank or the viability of underground propagules. The maturity of young animals

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[1] Editors' note: please refer to the Foreword for comments on prescribed fire terminology.

at the time of the fire may affect their survival in the area. Soil moisture content influences the effect on below-ground systems (Kozlowski and Ahlgren 1947).

It has become increasingly clear that variation and the average conditions of both fire behavior and fire effects can be shown only when viewed over a long time period and many fires. Fire behavior and effects depend on numerous and highly variable fuel and weather factors. Fuel amount and arrangement largely depend on the vegetation on the site and plant succession that produces fuel. Vegetation type depends on long-term factors such as soil and climate; succession, in turn, depends on the time elapsed since the last burn or other disturbance, the climate during that time, and other growing conditions of the site. Shorter term factors such as the previous season's precipitation and the current season's temperature, humidity, and rainfall also play an important role. Even short-term or transitory phenomena like windspeed and direction determine the results from an ignition source and the resulting fire behavior. I feel that any attempt to mimic a natural pattern would be arbitrary at best. Can human-caused fires be expected to account for all these variables and reproduce a natural occurrence?

Throughout history the purposes for which we have prescribed fires have remained fairly constant, although methods have changed as we have improved our ability to modify our environment. Fires have been and continue to be used to aid in collecting or growing food and fiber, to clear land for settlement, to discourage enemies, and to eliminate unwanted plant material (Pyne 1982). Continued research on prescribed fires will tell us much about how to obtain the best results from such procedures. If, however, we want to learn more about how these efforts affect some aspects of the ecosystems we live in, we must know more about natural fire ecology: How does natural fire relate to its environment and how does the environment affect natural fire?

Accidental fires may also produce unnatural effects. In systems where lightning-caused fire is infrequent but fuels are abundant, accidental fires may produce a much shortened fire return interval which would be unnatural. They also tend to cluster around places of human occupation. In Yellowstone National Park, 89 percent of the accidental fires were within 1 mile (1.6 km) of a road or campsite accessible by mechanical means. If this pattern occurs in areas able to burn frequently, this clustering of ignitions would tend to keep those areas in younger successional stages than would nature, especially if no suppression action was taken. If management objectives in those areas are to maintain natural systems, such a result is not acceptable.

In some (perhaps most) of our wilderness areas, nonwilderness values either inside or outside the wilderness would be at too great a risk to allow fire to play a completely natural role. Prescribed fires may be a better alternative than attempted total suppression in those areas; but they should be viewed as another management option, not a return to nature.

CONCLUSION

Our continued existence on this planet depends on how in tune we can become with our environment. Forces that are too disruptive to ecosystems are eventually eliminated, either because other environmental forces expel them or because they destroy the systems upon which they depend. We need to learn more about the forces that shaped the ecosystems in which we live if we are to fit ourselves into the ecosystems rather than being constantly at war with them. To learn how to do this, we need areas where fire can respond to all natural environmental conditions without human interference. This includes both time and place of ignitions.

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MANAGEMENT IMPLICATIONS OF IGNITION SOURCE IN PARK AND WILDERNESS FIRE MANAGEMENT PROGRAMS //

O. L. Daniels and L. D. Mason

ABSTRACT: In making decisions about ignition sources, the land manager must consider five variables: biological, physical, economic, political, and social. Planned ignitions[1] have significant positive and negative impacts on ecosystems neither of which is fully understood. One part of the clarification process will be to determine the effects of aboriginal burning and their implication for policy making. A system of monitoring lightning ignitions is proposed to identify burning objectives. Caution is essential in decisions to use planned ignitions, which should be restricted to areas where there is no alternative.

INTRODUCTION

After many years of policies of total fire suppression, the U.S. Department of the Interior, National Park Service, and the U.S. Department of Agriculture, Forest Service, began 15 years ago to reintroduce fire into wilderness ecosystems. In national forest wilderness, most of the reintroduced fire has been caused by lightning and allowed to burn. Any human-caused fires were suppressed, and only selected natural starts were permitted to burn. In recent years, there has been growing pressure to use human-ignited prescribed fire in wilderness. Behind this pressure is the desire to reestablish more natural fuel loadings and plant communities. Secondary reasons are to maintain other benefits, such as attractive, large "yellow bark" ponderosa pine or threatened and endangered plants and animals.

The case for human-ignited fire is logical and easy to state; the practical management implications, however, are complex and less straightforward. Our purpose is to explore those managerial implications. Our experience has been in the National Forests of the Northern Rocky Mountains and we will emphasize these situations.

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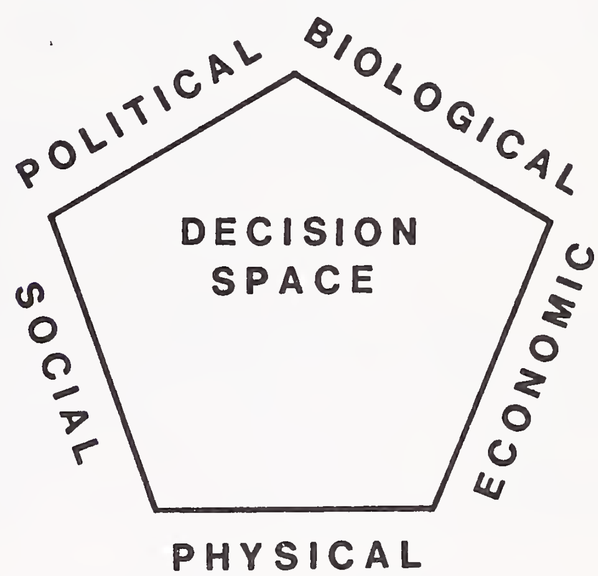
GENERAL MANAGEMENT PERSPECTIVES

The manager's job is somewhat different than that of the other professionals in land management. The researcher, scientist, and resource specialist make recommendations in their respective areas of expertise; the decisionmaker then must blend these recommendations and other variables into an acceptable and workable decision and course of action. Compromise is often necessary. A short review of the variables involved and their use is worthwhile.

The land manager's decision space is normally bounded by five variables, and any decision to be workable must be within acceptable limits of all of the variables. The variables are classified as biological, physical, economic, social, and political. It is useful to display the decision space in the following manner:



An in-depth discussion of these variables would be lengthy, but they can be summarized as follows:

Biological.--The ecosystems in which one is working.

[1]Editors' note: please refer to the Foreword for comments on prescribed fire terminology.

Physical.--The physical properties of the environment such as water and air quality. They may affect the local ecosystems or areas outside the local system.

Economic.--The variables of project budgets, long-term economic return, and allocation of resources among competing needs.

Social.--The concerns of people affected by the decision.

Legal/political.--The significance of legal requirements is self-evident. Political includes the opinions of elected officials such as key members of Congressional and oversight committees.

Today's managers normally use an interdisciplinary team to aid them in formulating line decisions. That team usually includes a social scientist and economist as well as physical and biological scientists. Regardless of team composition, managers must be sure all factors are considered. The issue of using human-ignited fires rather than natural ignitions involves all of these variables and is therefore complex.

BENEFITS OF USING PLANNED IGNITIONS IN WILDERNESS

The following discussion is based on a list of benefits from using planned ignitions in wilderness that appeared in a recent briefing paper prepared for the Chief of the Forest Service:

1. "Provides for more timely restoration of wilderness characteristics than total dependence upon unplanned ignitions." The fact that wilderness characteristics have been adversely affected by fire suppression is well documented. To depend upon natural ignitions, while suppressing some of them because they pose an unacceptable risk, can cause long delays in restoration. Planned ignitions at times speed up the process, and use of planned fire in this manner would diminish as soon as wilderness characteristics are restored. In the long term, planned use of fire could be minimized as is consistent with the overriding philosophy of wilderness management.

2. "Provides for an eventual opportunity to reintroduce the role of lightning caused fires in some wilderness ecosystems where risk of doing this now is unacceptable." In some situations the chance of a lightning-ignited fire occurring under acceptable burning conditions is extremely remote. When unnatural or excessively heavy fuels are also present, the entire drainage may be excluded from natural starts. If human-ignited fires occur in early or late fire season, the fuels can be reduced, and as fuel loading is reduced, more lightning-ignited prescription fires can be permitted. Planned use of fire near wilderness boundaries could reduce the potential for escape at critical points such as saddles that provide fuel continuity to areas outside the wilderness. This would be particularly beneficial in areas where the landforms provide partial natural barriers in fire spread, for example, Lincoln-Scapegoat, Bob Marshall, and the Idaho/Montana border of the Selway Bitterroot.

3. "Provides a means of reducing or minimizing adverse impacts, including adjacent and downstream resource value by permitting control over the location, timing, size, and intensity of planned ignition." The potential for adverse impacts to adjacent and downstream resource values is a major constraint to using unplanned ignitions. In some wilderness areas, the overriding constraints of size, proximity to population centers, airshed concerns, and public safety preclude all but limited use of unplanned prescription fire. If fire is an integral part of the ecosystems, planned ignitions can be used to approximate the natural conditions, if the event is timed to minimize cost, smoke impacts, public conflict, and risk of escape. In such cases, planned use of fire with deliberate ignitions may be necessary to maintain desirable fire effects.

4. "May be more acceptable politically and socially." Planned ignitions provide an opportunity for input before the event and may lessen the uncertainty associated with the wilderness fire program.

5. "May provide for ecosystem improvement for some threatened and endangered species." Many of the implementation clauses of more recent wilderness legislation have identified several secondary resource objectives. These secondary objectives include preserving threatened and endangered species, big game, esthetic values, and watershed. Wilderness management regulations emphasize these secondary values less than the need to maintain natural ecosystems. Prescribed fire can be conducted, however, in a manner that accomplishes both objectives; for example, the grizzly bear is a threatened and endangered species that benefits from fires occurring in its range. Fire has been excluded from many grizzly bear areas for a considerable time; the result has been deterioration of the wilderness ecosystem and grizzly bear habitat. A well-planned and well-executed prescribed fire could restore the wilderness ecosystem and improve grizzly habitat.

NEGATIVE IMPACTS OF PLANNED IGNITIONS

Most benefits of planned ignitions are associated with achieving basic wilderness objectives; most negative impacts are associated with the potential for damaging the wilderness and not achieving objectives. The foremost goal in establishing wilderness areas was to set aside areas that would remain free, or nearly free, of human impacts. Introducing planned fire into the wilderness is clearly a manipulation of this environment. Close monitoring will be necessary to ensure wilderness protection and the achievement of secondary objectives.

Because human-ignited fires are not a natural part of the ecosystem, the decision to ignite a fire must be even more soundly based than the decision to allow natural starts to burn. Research on the natural frequency and intensity of fires and the effects of fire on wilderness ecosystems is recent, and extensive data are restricted to a few locations. The generalization of research findings into broad management applications and baselines is difficult, in the case of wilderness fires, the state-of-the-knowledge leaves a lot to the unknown. Planned burning based on the knowledge base we have today has significant, if not high, potential for producing effects that would not occur under natural conditions.

An example of the lack of firm data on which to base fire frequency and intensity objectives is the issue of aboriginal burning. Should we or should we not try to duplicate Indian-started fires? Much of the literature to date favors including the effects of aboriginal burns in the baseline data for wilderness ecosystems; however, the question has not been addressed by policy-makers. Including or excluding the effects of aboriginal burning could significantly affect the results to be achieved. The sketchy data to date indicate that aboriginal burning in some parts of the Northern Rockies was recent and had few long-term effects on ecosystem development. Much more knowledge is needed, however, before we attempt to duplicate aboriginal fire frequencies in wilderness.

Planned ignitions in wilderness may have negative impacts on the management of lands and airsheds surrounding the wilderness. Each planned ignition will compete for dollars and personnel. If fires are properly managed, the impact of smoke on the airshed will be less than would be with unplanned ignitions. At the same time, it may reduce the land manager's ability to accomplish objectives outside the wilderness. Implementing a planned wilderness fire program places a new demand on finite budgets and on the capacities of the environment and the public to accept change. These budgets and capacities are often fully utilized requiring displacement of old activities to accept a new activity.

In addition, planned ignitions in wilderness will require committing budgets and personnel to the control side of management. To date, the emphasis has been on the need to have fire in wilderness and on the kinds of fire and fire effects desired. Little thought has been given to monitoring and evaluating implementation and to identifying needed adjustments. Forging ahead into a planned ignition program without a well-thought-out system of controls will likely create public controversy and ultimately reduce program effectiveness. Such reactions are possible because for the past 10 years we have gained acceptance for "nature doing her thing" in wilderness. Because of the expectations that have been created, some people will actively oppose a perceived manipulation of the ecosystem. Others will criticize the fires because of cost or any unexpected damage they cause. Still others may see it as an opportunity to push their own programs in wilderness. A few years ago, water users in the Columbia River Basin wanted to seed clouds to produce "average" snowpacks in the Bob Marshall Wilderness. If we decide to create average fire frequencies, we will be less able to argue against other manipulations of the ecosystem.

MONITORING

As indicated previously, one negative aspect of planned ignitions in wilderness is the potential for error; data are not yet complete enough to establish sound frequency and intensity objectives. One possible solution is to monitor the natural starts that are suppressed; projections of probable effects can enable managers to reproduce those effects through planned ignitions. The skills in fire behavior and fire effects needed to make these projections are already available. It would also be possible to evaluate suppressed ignitions that have occurred over the past few years. The risks of using the monitoring approach described would seem to be fewer than those associated with the use of historical data.

CONCLUSION

There are positive and negative aspects to human-ignited fire in wilderness. The negative aspects must be considered. Some of the principal problems are difficulty in defining fire frequency and intended objectives, the potential for unintended manipulation of the ecosystem, and a variety of economic, social, and political constraints. It follows that we should be cautious in using such fires in wilderness. If we do use planned ignitions, we should restrict them to those portions of the wilderness where the need is clear and where we have no alternative.

DOES NATURE REALLY CARE WHO STARTS THE FIRE?

C. E. Van Wagner

ABSTRACT: The shortest answer to the title question is that a fire's effect is independent of its mode of origin. So, rather than recreating the original fire regime per se, it might be more feasible to aim for the vegetation a natural fire regime would create. How to arrange the necessary fires then becomes a practical rather than a philosophical problem.

INTRODUCTION

The shortest answer to the question "Does nature really care who starts the fire?" is "No." I know of no laws of physics that support the argument that a particular fire's behaviour depends in any way on its mode of ignition once it has left the immediate vicinity of its point of origin. It follows that the effect of any fire should also be independent of how it started. Let us say, then, that the vegetation cannot tell the difference between lightning and any of the various ways in which people start fires.

Perhaps, one might argue, the spatial pattern of fire starts or the average fire behaviour might depend somewhat on how fires get started. For example, over a long period of time, lightning fires may be more evenly distributed over the landscape than human-caused fires along a road or trail system. Or, because lightning is usually accompanied by rain, the fire size and direction of spread may be influenced by the pattern of wet and dry areas after a storm, in a way that human-caused fires started in clear, dry weather are not. But all this, I think, is just minor qualification of the main answer: that nature does not really care how the fire starts, whether by lightning or humans, whether accidently or maliciously, or as prescribed fire lit for a purpose.

Suppose we ask another question, which may well be what the symposium authorities really had in mind when they phrased the question in my title: "Do we the people really care how the fires are started?" This slightly different question opens up a further set of problems and questions, some of which are as much a matter of philosophy as of science. I suppose that the science is relatively easy and the philosophy relatively difficult. I also suppose that we had better get both right before setting large-scale, long-term operations in motion.

With respect to fire, then, what are we really looking for in our parks and wilderness areas? Is it:

1. A set of fires ignited under the same conditions and by the same means as in primeval times, that is, the so-called "natural fire regime"; or

2. The vegetation that a natural fire regime would have created?

There is, it seems to me, a world of subtle difference between these two concepts. Most of the ideas that follow can be found in a treatment of this question with respect to the Canadian national parks (Van Wagner and Methven 1980).

THE NATURAL FIRE REGIME

Consider the concept of "natural fire regime." The first problem is defining the word "natural" as it applies to influences on vegetation. My private interpretation is simply that any factor that has been in effect long enough for the vegetation to come into equilibrium with it can be called natural. By this criterion, I suppose that the natural fire regime at the time of white contact would have included lightning fires and the fire load produced by the activities of native people, whether accidentally or deliberately. The vegetation at the moment that Europeans arrived was presumably in equilibrium with that fire regime. But observe that the concept of natural fire involves much more than just mode of ignition. It includes also the idea that all "natural" fires be allowed to spread with complete freedom at any intensity, and at the same time in the total absence of all "unnatural" fires.

I take it for granted that the re-creation of a truly natural fire regime in modern times is impossible for a host of social as well as physical reasons. We are, then, left--whether we like it or not--with the other alternative goal: "the vegetation that a natural fire regime would have created." If this point is accepted, it follows that the mode of ignition becomes almost irrelevant. Instead of a fire plan taking precedence, the governing instrument becomes the vegetation plan. The fires then follow in consequence by whatever means are feasible and necessary.

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THE NATURAL VEGETATION

Shifting the focus from the fires themselves to the vegetation has a major consequence that is both a complication and a challenge. If we could simply re-create the complete set of natural fires, we could then accept with blissful confidence that whatever vegetation resulted would be correct naturally. But, if this simple path is denied us, we have no responsible alternative but to enquire into the links between fire and vegetation and: (1) decide what kind of vegetation we want, (2) design a fire regime that will produce it, and (3) carry out the operations by one means or another.

At the same time, this view of the question relieves some of the philosophical pressure concerning mode of ignition. Instead of asking whether a fire is natural or unnatural, the distinction that counts is between wanted fire and unwanted fire. The criterion is the vegetation plan. An intriguing point now emerges.

Of all natural forces that affect vegetation, fire is the only one that pervades the landscape at large, whose accidental occurrences can be controlled, and which can also be applied at will within a chosen area at a chosen time. It is thus the only management tool available to any land unit on which the use of artificial means such as machinery or chemical sprays is denied. On such areas, which include both the Canadian and American national parks, the vegetation will therefore be managed with fire or it cannot be managed at all.

Choosing the desired vegetation is therefore the first step. Perhaps a reasonable goal is simply to perpetuate the vegetation now present. Or a philosophically ideal answer might be "that native vegetation in the best long-term equilibrium with the primeval natural fire regime." Whatever goal is decided upon must be compatible with the means available to achieve it. If fire is the only available tool, then the vegetation goal must be compatible with what can be achieved by managing fire.

THE PRACTICAL FIRE REGIME

The first question in the design of the appropriate fire regime will be: "What should be the average age of the vegetation or of time-since-fire?"

From the fire viewpoint, this translates into: "How much of the area should burn annually on the average?"

The answer is the reciprocal of the fire cycle and gives for a lethal fire regime the annual renewal rate of the vegetation. Where the fires are generally nonlethal, it gives simply the average length of time between fires at a point.

The second major question concerns the distribution of the intervals. Any vegetation system cycled by periodic fire has many faces, from freshly renewed to what might be called decadent old age. Such an ecosystem is not properly represented unless all faces are present. Thus a major feature of the landscape is, in a lethal fire regime, the age-class distribution. In a nonlethal fire regime, the distribution of time-since-fire will create an analogous pattern. This distribution of age classes or time-since-fire is an integral part of the vegetation plan, which is not complete without an answer to the question: "What is the desired form of the spatial distribution of time-since-fire?" This question has several possible answers, for example: the rectangular distribution in which stands are renewed at a single mature age, as if the vegetation were flammable at that age only (given as an artificial example); the negative exponential (Van Wagner 1978), in which stands are renewed at random, as if the vegetation were uniformly flammable at all ages; or the Weibull distribution (Johnson and Rowe 1977), which lies intermediate between the first two, as if flammability generally increased with age.

Again, the analogy of "time-since-fire" applies in a nonlethal fire regime. Having already estimated how much of the are to burn annually, we now have a guide as to where to expect or plan the fires (as the case may be).

The third major question deals with the problem of scale, both in space and time. Most parks and wilderness areas, being of limited size, must be managed as microcosms of the real world in which the very large fires that might occur in a state of nature would be considered undesirable. Furthermore, wide swings in burned area from year to year or decade to decade might also be most unwelcome. The question is, then, "What are the desired distributions of fire sizes and total annual burn?"

Ability to control these factors is presumably essential. Otherwise, a park could wind up at any time with some sizeable proportion of its vegetation in a single age class, to say nothing of the repercussions of fires escaping outside their preestablished boundaries.

These three questions, although worded in terms of fire, in fact proceed directly from the plan that describes the vegetation to be maintained within the chosen area and its pattern in space and time. However the fires spring into being and whatever the degree of control over their frequency and size, each fire contributes individually to this overall pattern and is seen to do so by the park management. Only from this viewpoint of the landscape as a whole, it seems to me, can the problem of maintaining fire-dependent ecosystems be approached with some hope of practical solution.

The obvious concern that now arises is the degree of artificiality that these questions' answers seem to imply. There are two points to be made on this score: (1) If the management mandate is set in terms of the vegetation rather than of fires only, these questions are hard to avoid, since their answers provide the basic means by which the vegetation must be described in terms of fire. (2) The answers do not of themselves force any particular degree of intervention. At least, they provide the yardsticks for measuring the degree to which the mandate is being carried out. At most, they provide guides to whatever intervention is undertaken.

THE FIRES THEMSELVES

It is one thing to ponder our problem philosophically and even to devise scientifically logical plans for meeting our goals. It is obviously quite another thing to be faced with the task of carrying them out. Even if park managers could bring themselves to face the amount and intensity of fire that might be needed to maintain the desired vegetation, it is the time-and-space scale problem that will always provide the major practical stumbling block. Once it is accepted that no class of accidental fires, not even of lightning origin, can be allowed to spread absolutely without control, then two points follow almost inexorably. The first is that an effective fire control force will have to be in place. The second is that the desired vegetation pattern in areas of limited size can probably never be achieved without some deliberately started prescribed fires. These latter offer, obviously, the best chance of confining fire to chosen areas at chosen times. Perhaps a combination of lightning fires allowed to run and prescribed fires, deliberately set and confined to specified boundaries, offers the most attractive fire regime from the philosophical and practical viewpoints. Heinselman (1973) has treated this subject and its ramifications in depth. Whatever the pattern of fires that ultimately make up the practical operational fire regime, it is the vegetation plan that must be able to bear the brunt of philosophical justification rather than the fires per se. The fires become the means to an end rather than the end in itself.

CONCLUSION

The question we started with refers figuratively to "Nature" as if she were a self-conscious entity that cares about how fire is started. I hope you will consider that question answered, even though I have strayed somewhat from its original narrow context. It seems that, whether we like it or not, we are about to take over Nature's ancient role in the management of fire-dependent ecosystems in certain areas called "wilderness." I only suppose that, if Nature is really conscious, she must be vastly amused at the trouble we have in duplicating something she has been doing so easily for untold thousands of years.

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FIRE REGIMES AND MANAGEMENT OPTIONS IN ECOSYSTEMS WITH LARGE HIGH-INTENSITY FIRES

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ABSTRACT: Large stand-replacing fires at intervals of 50 to 500 years were responsible for the vegetation patterns of parks and wilderness areas in the Boreal, Great Lakes-Acadian, Rocky Mountain, and Douglas-fir regions. Fire recurrence is closely linked to stand age in some ecosystems. Prescribed crown fires and underburnings could help begin fire management safely. In the far North, natural crown fire regimes still exist, and in some Rocky Mountain units such fires are being successfully managed. Improvements in techniques and fire control technology should make fire management feasible in more areas. Restoration of natural regimes is vital to preserving landscape diversity.

INTRODUCTION

In presettlement times certain ecosystems within some of North America's finest wilderness areas and national parks had fire regimes characterized by episodes of large high-intensity forest fires. Such fires killed most of the forest over large areas, resulting in stand replacement by new and relatively even-aged generations of trees. These periodic fires regulated nutrient cycles, energy flows, wildlife habitat, insect and disease outbreaks, and the vegetation and forest age-class mosaic on the landscape. Such ecosystems were truly fire-dependent. In some areas, stand-replacing fires occurred at intervals as short as 50 years, whereas in others the return intervals were hundreds of years. There were also important differences in fire size, plant communities, fuels, and other factors. Fire management programs for parks and wilderness areas having regimes of this kind pose difficult fire control and safety questions as well as complex ecological alternatives (Kilgore 1983). Some large fires are virtually inevitable in most areas, however, and fire exclusion is not a realistic option. The purpose of this paper is to describe some of the variations in fire regimes in such areas and to explore management alternatives.

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By fire regime, I mean the kind of fire activity that characterizes a specific region. Its elements are (1) fire type and intensity (crown fires, severe surface fires, or light surface fires), (2) size of significant fires, and (3) fire intervals for specific land units. The average time required for a fire regime to burn over an area equivalent to the total area of an ecosystem is the fire rotation (Heinselman 1973) or fire cycle (Van Wagner 1978). Fire is really not so orderly, however, because some areas are skipped for long periods, whereas others burn two or more times during a rotation (Heinselman 1978, 1981a; Romme 1980b). In regions with large high-intensity fires, I include regions with a substantial probability of running crown fires or stand-killing surface fires covering more than 1,000 acres (405 ha) where such fires were a significant factor in producing new forest age classes. The regions that had or still have regimes of such fires include (1) the Great Lakes forest in Canada and the United States, (2) the New England and Acadian pine and certain spruce-fir forests, (3) the Canadian and Alaskan boreal forest, (4) the Rocky Mountain subalpine and upper montane zones from Alberta to Colorado and Utah, and (5) the Douglas-fir region of the Pacific Northwest, including the coastal Douglas-fir zone on the west slopes of the Cascades and the interior *Abies grandis* zone (Heinselman 1978, 1981a).

REGIONAL DIFFERENCES IN FIRE REGIMES

There are important regional differences in the prevalence of stand-replacing fires, in return intervals and rotations, in fuel relationships to stand ages, in the relation of major droughts to fire size and intensity, and in other factors. A complete review is beyond the scope of this paper (see Heinselman 1978, 1981a, 1981b; Arno 1980; Stokes and Dieterich 1980; Alexander 1983). Here I can only highlight certain important differences.

Canadian And Alaskan Boreal Forests

Canadian and Alaskan boreal forests are the easiest to summarize because most ecologically significant fires in this region were, and still are, large stand-replacing crown fires or high-intensity surface fires. Lightning-caused fires still account for 70 to 99 percent of the area

burned in remote areas, especially in the unexploited northern boreal forest and in the subarctic spruce-lichen woodlands. Here, where suppression has had minimal effect, a nearly natural lightning fire regime still prevails. In the main boreal forest the dominant regime was one of high-intensity, short to long return interval crown fires or severe, large surface fires--often more than 25,000 acres (10 000 ha) and sometimes more than 1 million acres (405 000 ha). Rotations were shorter in the drier regions of northwestern Canada and interior Alaska, where they probably averaged 50 to 100 years, than in Ontario and Quebec, where they may have averaged 100 to 300 years. Rotations near tree line in the western subarctic spruce-lichen woodlands probably average 100 to 150 years. In southeastern Labrador, rotations are nearly 500 years (Foster 1983). Near Wood Buffalo National Park and adjacent areas in the Northwest Territories some jack pine forests have regimes of medium-intensity surface fires at intervals of 25 years or so that do not result in total stand replacement. Similar regimes may also occur in some lodgepole pine forests farther west. The longest fire intervals in the western boreal probably are in floodplain white spruce, where rotations up to 300 years prevail. Throughout the boreal region, major outbreaks of lightning-caused fires occur in semirandom patterns during unusually dry summers, which occur in any subregion at least once every 10 to 20 years. In the intervening years some fires occur nearly every year, but most of the area is burned in major drought years. It is not clear whether mature forests are much more prone to ignition than younger stands. Once a major fire is in progress, however, several age classes may burn including some younger stands (Rowe and Scotter 1973; Viereck 1973, 1981; Johnson and Rowe 1975; Rowe 1979, 1981; Foster 1983; Heinselman 1978). I lack specific fire history data for the newer western boreal national parks in Canada and Alaska, but many of the above generalizations probably apply. Many of the new parks, such as Kluane and Wrangell-St. Elias, are in high mountain ranges atypical of most of the boreal region, and maximum fire sizes may be smaller because of the tendency for fires to run upslope to timberline, whereas the spread of fires in the more level terrain of the main boreal region is nearly unlimited.

Great Lakes, New England, And Acadian Forests

The presettlement Great Lakes, New England, and Acadian forests had several distinct fire regimes, depending on the subregional climatic and physiographic setting. Enclaves of boreal jack pine and spruce-fir forests had stand-replacement crown fires or surface fires on rotations of 50 to 100 years in the West and perhaps 150 to 200 years in the higher precipitation areas of the East. Logging has altered the stand composition and age-class mosaic of most parks and wilderness areas within such forests except for large areas in Quetico Provincial Park in Ontario and the Boundary Waters Canoe Area Wilderness (BWCAW) in Minnesota. There, many burns were large--some exceeding 250,000 acres (101 000 ha) (Heinselman 1973). White pine and red pine forests had different fire regimes, but logging has so altered most of those forests that it has only been possible to decipher presettlement fire regimes in the BWCAW and Itasca State Park in Minnesota and in Algonquin and Quetico Parks in Ontario. There the fire regime was one of periodic moderate-intensity surface fires that eliminated understories but killed few mature trees. These fires had return intervals of 20 to 40 years. More intense fires that killed most of the stand introduced new age classes at intervals of 150 to 300 years. Fire areas are not well known, but some were clearly large (Hansen and others 1973; Frissell 1973; Heinselman 1973; Cwynar 1977; Woods and Day 1977). There were fires somewhere in these reserves nearly every year, but most of the ecologically significant burning occurred in major drought years that recurred at 20- to 40-year intervals. Black spruce and tamarack bog forests associated with the Laurentian uplands or with glacial moraines and outwash deposits often burned in the same fires that burned the uplands, but some were skipped by many fires and had longer rotations (Heinselman 1981a). Mixed aspen-birch-conifer forests had regimes of high-intensity surface fires or even crown fires where their conifer elements were sufficient. Outbreaks of the spruce budworm killed balsam fir stands over vast regions at intervals of 40 to 70 years, creating tremendous fuel peaks in both the Great Lakes and Acadian regions. Old conifer forests are probably more prone to lightning ignitions and crowning or intense surface fires than younger stands, but some young stands will support crown fires. In New England and the Acadian region, fires in white pine and spruce-fir probably were similar to those in the Great Lakes forests, but return intervals and rotations were longer (Wein and Moore 1977). The spruce-fir forests of the higher Adirondack and New England mountains saw little fire.

Several significant high-intensity fires have occurred during the suppression era in parks and wilderness areas of the Great Lakes and New England region: the Isle Royale fires of 1936; the Quetico fires of 1936, 1961, and 1972; the BWCAW fires of 1936, 1971, 1974, and 1976; the Baxter State Park (Maine) fire of 1977; and the Bar Harbor fire (Acadia National Park, Maine) of 1941. Most of these fires occurred during major droughts and had the potential to become much larger. It is a tribute to modern fire control technology that none except the Quetico and Isle Royale fires of 1936 burned more than 15,000 acres (6 000 ha). We have demonstrated that we can suppress most wilderness fires in this region, although some may reach the 10,000-acre (4 000-ha) range before control is achieved.

Rocky Mountain Upper Montane And Subalpine Forests

The fire regimes of the Rockies are complex, largely because in mountainous regions there is so much variation in climates, topography, vegetation, and productivity. It is important to understand such variations because so many large national parks and wilderness areas occur in this region.

Some common fire regimes in ecosystems with large intense fires were these:

1. In the western hemlock-western redcedar forests of warm, moist valleys and uplands in northwestern Montana and Idaho, eastern Washington, and southeastern British Columbia, a common regime was one of high-intensity stand-replacement burns at intervals of 100 to 300 years or more. Sometimes surface fires failed to crown out and served mainly to thin stands. These forests burn only during extreme droughts but then can generate massive crown fires such as the Sundance Fire of 1967 near Bonners Ferry, Idaho, which burned 56,000 acres (23 000 ha), most of which burned on September 1 (Davis and others 1979; Arno and Davis 1980).

2. In the upper montane and lower subalpine of northwestern Montana and northern Idaho, some sites are dominated by Douglas-fir, western larch, and sometimes western white pine, as well as the more ubiquitous lodgepole pine, Engelmann spruce, and subalpine fir. In these forests moderate- to high-intensity surface fires that scarred but did not kill larch were common at intervals of 10 to 30 years. Under severe drought conditions, large crown fires occurred on some sites at return intervals of 140 years or so (Arno 1976, 1980; Davis and others 1979; Davis 1980).

3. In the lower subalpine regions of many eastern and interior Rocky Mountain ranges, lodgepole pine forests merge with Douglas-fir savanna in open parklike forests along the drier valleys. This is common vegetation in parts of Yellowstone, Grand Teton, Glacier, Jasper, and Banff National Parks. The typical regime in these situations was one of frequent and often small moderate-intensity surface fires that scarred many trees but only killed young Douglas-fir and occasionally lodgepole pines. This regime maintained many-aged savanna-like stands. Average return intervals for such fires in a given stand were in the range of 15 to 30 years (Houston 1973; Loope and Gruell 1973; Arno 1976, 1980; Tande 1979).

4. In the main subalpine zone of many mountain ranges the principal upland tree is lodgepole pine, often mixed with Engelmann spruce and subalpine fir. Spruce and fir predominate along streams and valley bottoms. In this zone the most common regime was probably fairly large stand-replacing crown fires in rotations of 50 to 150 years; however, in some situations the rotations were as long as 300 to 400 years (more on this later). A classic crown fire sequence sometimes occurred in this zone after a crown fire produced dog-hair stands of lodgepole and a dense snag forest of standing dead trees. Some 40 to 60 years later the snags create a jack-straw of dry woody fuels amidst small-diameter new lodgepole pine with closely packed crowns and many dying suppressed individuals. At this stage a second lightning strike sets off another holocaust, and the process is repeated. The infamous Sleeping Child Fire of August 1961 on the Bitterroot National Forest has produced just such a stand. This fire burned 28,000 acres (11 000 ha) of old beetle-killed lodgepole pine. The most intense crown fires probably occurred on cool, moist north slopes and other more productive sites where ladder fuels were provided by a spruce-fir stand component. Such stands burned at longer intervals during major droughts (Arno 1976, 1980; Day 1972; Gabriel 1976; Habeck and Mutch 1973; Habeck 1976; Romme 1980a, 1982; Tande 1979; Wellner 1970).

5. In the upper subalpine region, where Engelmann spruce, subalpine fir, lodgepole pine, and whitebark pine are the principal trees, soil moisture is usually high, temperatures are cool, and snow lingers into early summer. Fires are not frequent in these forests, but under extreme drought conditions they can burn fiercely, and stand-replacing fires may occur. Rotations are long--probably 150 to 300 years or more. Some fires run up into tundra, but most go out before reaching tree line (Tande 1979; Arno 1980).

With this review of "typical" fire regimes as background, it is useful to consider a different situation in Yellowstone National Park, where lodgepole pine is the principal tree. Here Despain and Sellers (1977), Romme (1980a, 1982), and Romme and Knight (1982) have found that many "younger" lodgepole stands will not sustain crown fires. There is a close relationship between flammability, stand age, and stand composition. Most stands are not susceptible to crown fires until they develop a significant understory or canopy component of Engelmann spruce, subalpine fir, or both--usually not until about 300 years after fire. This means that the probable path of fires can often be predicted by mapping out old stands with adequate spruce and fir ladder fuels downwind from ignition points. Because such stands are often not really large, crown fires in recent managed fires have only ranged from 1,000 to 8,000 acres (405 to 3 200 ha). Landscape diversity seems permanently linked to age classes and established fire patterns in such areas (Romme and Knight 1982). Despain (1983) has also shown that large areas of lodgepole pine have essentially no spruce-fir component and are self-perpetuating all-aged pine stands that are essentially "climax" on the dry, infertile rhyolitic soils where they occur. The oldest pines in these stands often exceed 300 to 400 years in age, yet the stands show no evidence of fire since establishment.

Tande's (1979) fire history study of a portion of Jasper National Park, Alberta, produced the only published stand origin map for a large unit of the

Rocky Mountain subalpine. Such maps allow estimates of the percentage of existing forests that originated from specific stand-replacing fires and show the actual paths of many fires in relation to topography, aspect, and other factors. He mapped 46 fires between 1665 and 1975 that had a mean fire interval of 5.5 years, but only 26 of these fires burned more than 1,200 acres (486 ha). Most of the existing forest actually originated after the fires in three years (1758, 1847, and 1889), each of which burned more than half of the area. The mean return interval for these major fires was 65.5 years. Multiple-aged stands maintained by frequent surface fires dominated the lower-elevation Douglas-fir/lodgepole pine savannas, whereas large continuous even-aged lodgepole pine and spruce-fir forests dominated higher elevations where mesic moisture regimes allowed greater fuel accumulations and therefore more intense fires during major droughts. The 1889 fires burned 78.5 percent of the area, and 1889 stands are still the most abundant.

The contrast between Yellowstone's fire history and Jasper's history underscores the importance of knowing the actual history of each park or wilderness where fire management planning is done. Evidence that the Yellowstone situation is not unique comes from the Savage Run Wilderness in southeastern Wyoming, where Romme and Knight (1981) have shown that lodgepole stands also do not burn until about 300 years after fire--when adequate spruce and fir ladder fuels permit crowning. Stream bottoms and valleys often reproduce directly to spruce and fir after fire but have return intervals in the 300- to 400-year range, probably because these sites are rarely dry enough to sustain fires and also escape ignition more frequently.

Pacific Northwest Douglas-fir Forests

In the Pacific slope Douglas-fir belt, vast old Douglas-fir forests existed when logging began a century ago. Fine examples of these forests still exist in such reserves as Mount Rainier National Park, North Cascades National Park, and the Glacier Peak Wilderness. It has long been known that most such forests postdated forest fires, but only recently have we begun to understand the real nature of the fires that produced these forests and the length of the regeneration periods that followed. Franklin and Hemstrom (1981) have now shown that many Douglas-fir forests over widely separated localities owe their origin to one or a series of major fires that occurred about 500 years ago. A major drought or series of droughts throughout the Cascades some 500 years ago, perhaps due to short-term climatic change, seems responsible. In many stands the period of regeneration after these fires was long--an age spread in the main stand of more than 100 years being common in 500-year-old forests. Suppression of fires probably has <u>not</u> increased flammability in these forests because young stands in their first 100 years seem more susceptible to fires than do old stands. Thus the real control of these fire episodes may be widely time-spaced climatic anomalies rather than factors related to stand age, species composition, or fuel concentrations. Fortunately, Douglas-fir and some of its associates are so long-lived (maximum ages over 1,000 years) that we can wait for more complete ecological information and better fire control technology before initiating fire management programs. The mixed forests of such Wilderness Areas as Pasayten in the drier interior regions of Washington and Oregon have complex fire regimes more like those of the Rockies (Fahnestock 1976).

FUEL RELATIONSHIPS TO STAND AGE AND TIME SINCE FIRE

An important question for fire managers of parks or wildernesses where high-intensity fires are possible is this: Can we predict which stands will ignite readily and sustain crown fires if we know the stand's age, species composition, and the time since the last fire? The answer is apparently <u>yes</u> for some areas, <u>no</u> for others, and <u>only if we consider other factors</u> for the rest. Each manager must know the local situation. I am not a fuels or fire control specialist, but below are a few key questions that must be answered for your area. They are all parts of this general question: Is fire a largely random factor, dependent on random human and lightning ignitions and the vagaries of weather, or is the probability of a successful ignition and subsequent development into a major fire controlled by fuel factors that increase systematically with stand age (Heinselman 1981b)?

1. Do standing fuels increase systematically with stand age?

2. Is the fuel content of surface organic layers important in ignition and in sustaining high-intensity fires, and does it increase with stand age?

3. Are there important long-crowned flammable conifers that increase in abundance with stand age, thus providing ladder fuels to aid crowning? Or, conversely, are stands lacking in ladder fuels or perhaps composed of long-crowned flammable conifers from the start?

4. Are there arboreal lichens or mistletoe brooms that increase with stand age to serve as flash fuels in the crowns?

5. Is dead timber from an insect outbreak vital as fuel? If so, do such outbreaks only occur in old stands or are they unrelated to age?

6. Are snag fuels from burns important? How do they relate to age?

7. Do stands ignite and crown easily, or will stands only ignite and crown under extreme drought and maximum burning conditions?

8. Do you know if young stands will in fact carry intense fires?

Answers to these questions will help you answer these further questions: Can we rely on younger stands as firebreaks, and can we identify potential fire paths by mapping out old flammable stands? The generalized answers are as follows: for the boreal forest and Pacific Coast Douglas-fir forests--usually not; for the Great Lakes and Acadian forests--sometimes, especially in aspen-birch forests; for the Rocky Mountain region--sometimes, but local conditions vary. Knowledge of the fire-stand age relationship will also help predict whether the reintroduction of managed fire may decrease the future potential for large fires.

RELATION OF SEVERE DROUGHT TO FIRE YEARS AND FIRE SIZE

One generalization that may hold is that most of the area of new forest age classes generated by stand-replacement fires was created by fires that burned in a few major fire years. We know since weather records became available that most such years are characterized by severe drought. In every region there are periods in most years when fires can be ignited, but most fires burn at low intensities, cover small areas, and soon go out. It is the big fires that burned under unusually favorable conditions that created the age-class patterns we see today.

Every region where stand-replacing fires were important has its list of major fire years--lists that are being refined with each new fire history study. Some of the known major fire years were:

Great Lakes region
  1695, 1755, 1758-1759, 1803, 1854, 1863-1864, 1871, 1875, 1894, 1910, 1918, 1923, 1929, 1936, 1961, 1974, 1976
Rocky Mountains
  1667, 1695, 1714, 1755, 1758, 1803, 1824, 1846-1847, 1864, 1871, 1889, 1892, 1910, 1961, 1967, 1981
Alaska
  1935, 1940-1941, 1946-1947, 1957, 1969, 1971, 1977
Western boreal region
  1803, 1864, 1881, 1889, 1892, 1894, 1898, 1905, 1911, 1917, 1940, 1946, 1953, 1958, 1968-1969, 1971, 1973, 1975, 1976, 1979
Central boreal region
  1923, 1929, 1936-1937, 1948, 1961, 1964, 1970, 1974, 1976, 1977
Eastern boreal region (Quebec)
  1932, 1941, 1944, 1953, 1955, 1977
New England-Acadian region
  1825, 1977
Pacific Northwest
  1933, 1970

(Arno 1976; Donnelly and Harrington 1978; Gabriel 1976; Heinselman 1981a; Rowe and others 1975; Stocks and Barney 1981; Tande 1979).

Some of these fire years show up in studies of widely separated areas within regions or even in different regions. For example, 1755-1759, 1863-1864, and 1910 were major fire years in both the Rockies and Great Lakes regions. Such years evidently saw droughts of subcontinental proportions. It is likely, then, that to achieve a natural rate of stand renewal we might need to allow considerable burning in major drought years, yet such years involve the very kinds of burning conditions that give rise to fears that managed fires cannot be confined to parks and wilderness areas. We must find ways to deal with this.

CAN POTENTIAL MAXIMUM FIRE PATHS BE PREDICTED?

Managers of areas with a history of large stand-replacement fires need a means of predicting maximum fire paths. A "worst case" analysis of potentially large fires can often be based on two independent methods. The first is the standard one of looking at drought buildup to the day of the analysis, projecting the extended forecast with a healthy margin for error, and then plugging in fuels and rates of spread calculations for the vegetation types in the expected path of the fire. For areas not greatly altered by past logging, an alternative approach is to look at the forest age-class pattern on the landscape in the fire area. Remember that most past fires that generated large stands of one age class burned under near maximum fire weather and drought buildup. By mapping out the classes ahead of the fire one can visualize possible fire paths and maximum runs. This is obviously not a firm predictive method, but it can give confidence to projections that a fire will not exceed manageable proportions if the age classes the fire is burning in do not extend beyond permissible limits. And conversely, it may raise a red flag if a single age class extends from the present fire far beyond such limits. Fire history has a way of repeating itself!

LESSONS FROM HISTORIC WILDFIRES OUTSIDE WILDERNESS

Catastrophic wildfires have occurred outside park and wilderness areas in every region. A close examination of some of the worst disasters shows that many were exacerbated by factors not present in parks and wildernesses. The greatest disaster fires in terms of loss of lives, property, and fire size surely include the following: the Miramichi in New Brunswick and Maine, 1825, 5 million acres (2 million ha); the Peshtigo in Wisconsin, 1871, 1,280,000 acres (518 000 ha); the Lower Michigan, 1871, 2,500,000 acres (1 million ha); the Thumb, Lower Michigan, 1881, 1 million acres (405 000 ha); the Hinckley, Minnesota, 1894, 160,000 acres (65 000 ha); the Baudette, Minnesota, 1910, 300,000 acres (121 000 ha); the Idaho and Montana Conflagration, 1910, 3 million acres (1 214 000 ha); the Matheson, Ontario, 1916, 640,000 acres (259 000 ha); the Cloquet-Moose Lake, Minnesota, 1918, 1,280,000 acres (518 000 ha); the Haileybury, Ontario, 1922, 1,280,000 acres (518 000 ha); the Tillamook, Oregon, 1933,

311,000 acres (126 000 ha) (Holbrook 1960; Haines and Sando 1969). These fires collectively killed several thousand people. All occurred in major drought years and maximum fire weather, mostly in late summer or fall. All were associated with large-scale logging that had recently left vast areas of untreated coniferous slash. Many were also associated with recent land clearing that had created open hay and brushlands--and fire was used in most clearing operations. These logging and land-clearing operations caused multiple ignitions that ultimately merged into massive conflagrations moving quickly across the semiopen landscape in fuels that permit much more rapid spread than do standing green forests. These are circumstances that hopefully will not be repeated. The fuels that fed these fires had little in common with most wilderness areas or parks.

When major fire years strike these regions again, some of the most threatening fires will probably be outside parks or wilderness areas. For example, in the recent severe 1976 fire season in my own state of Minnesota there were three fires in the 3,000-acre (1 200-ha) range in the BWCAW, but all were confined to the wilderness by national forest control teams. The largest and most destructive 1976 fire in Minnesota was not in wilderness. It was the Huntersville Fire, near Park Rapids, which burned 24,000 acres (9 700 ha) of jack pine and meadowland in 2 days and destroyed much commercial timber and several homes. Likewise, in Michigan in 1980 the Mack Lake Fire burned 20,000 acres (8 000 ha) of jack pine in 1 day, destroying 41 homes and summer cottages and killing one firefighter. It was an escaped prescribed fire on national forest land (Kilgore 1983). In contrast, the 1976 Seney Fire in Michigan did start in a small wilderness unit in sedge-grass peatland, and ultimately burned 55,000 acres (22 000 ha) of the Seney National Wildlife Refuge, plus some 18,000 acres (7 300 ha) of State and private forest lands beyond the refuge (Kilgore 1983).

The lesson is this: when major droughts hit these regions, there will inevitably be large forest fires. Parks and wilderness areas are no exception, but the greatest risk to lives and property lies in fires outside such areas.

FIRE MANAGEMENT OPTIONS

Before I begin this discussion we need some ground rules. First comes safety. Large high-intensity fires are by nature dangerous to human lives and property. This is the one constraint that limits most otherwise feasible options. No fire program is acceptable that imposes avoidable risks on visitors, fire management personnel, or residents and travelers outside the reserved area. Also it is unacceptable to permit avoidable risks to developed properties or commercial timberlands outside the park or wilderness. The visitor safety problem can often be avoided by closing all or portions of a park or wilderness to visitor use during extreme fire danger periods or by closing specific units where managed fires are burning. Objectives must also be clear. I am assuming the objective is to restore fire to its natural role in the ecosystem to the maximum extent feasible, consistent with safety concerns and other resource values. This objective is especially vital in ecosystems subject to large stand-replacement fires because much of the natural diversity in both forests and wildlife in such systems is between-patch diversity that depends on the renewal of forest age classes and vegetation patterns generated by fire (Rowe 1979; Heinselman 1981b; Romme and Knight 1982).

Effect Of Wilderness Or Park Size And Setting

The total area, shape, and geographic setting of a park or wilderness are factors that may limit options. The ideal unit is very large (I consider 1 million acres [405 000 ha] "large" in this context); nearly round or square; surrounded by natural firebreaks or nonflammable vegetation and by land devoid of cities, towns, residences, valuable developments, or commercial forests; and totally free of developed corridors or enclaves within its boundaries. No real-world unit has all these attributes, but some have many. These traits are important because each gives the manager more freedom to let fires achieve significant size without endangering lives or property. Isle Royale National Park is nearly ideal. Fires cannot possibly damage property or endanger lives beyond its borders, and current developments are almost totally confined to the extreme ends of the island. A small park in an urban or largely developed area, such as Acadia National Park, presents nearly insurmountable safety constraints. But even a large unit is too small to allow fires to achieve their full size potential in ecosystems where fires can burn hundreds of thousands of acres. In such cases fires must be limited to a reasonable fraction of the total area even if safety concerns are not involved.

Where Are Natural Fire Management Zones Feasible?

By "natural" fire management zones I mean areas within which designated lightning-caused fires will be allowed to burn under surveillance so long as they meet predetermined prescriptions. The reason for constraint is again safety. In an ecosystem where such fires have the potential to become running crown fires covering thousands of acres, it is prudent to establish such zones only where there is no chance that a fire will leave the unit or where there is full confidence that any fire leaving the unit can be suppressed inside the boundary with acceptable costs. The pattern of stand ages on the landscape can be used in making this judgment if the area has not been logged and has an array of stand origins that predate suppression activities. Another constraint is the possibility that free-roaming fires will cause unnatural damage to certain vegetation because of fuel accumulations or the development of flammable understories due to a long period of

fire suppression. This may be mitigated by suppressing fires that threaten such stands, or perhaps by suppressing only one perimeter of a fire if that will solve the problem. It can also be alleviated with prescribed fire, as I note below.

Is There A Place For Prescribed Fire?

Philosophically I have problems with prescribed fire in parks and wilderness areas because it is deliberate manipulation of a natural factor. I much prefer allowing lightning fires to do their work. The Forest Service does not now allow prescribed fires in wilderness, but the National Park Service does. Yet we must put aside philosophical reactions and current administrative policies and take a hard look at realities. There are two major situations where prescribed fire could be an important tool in restoring fire to these ecosystems. The first is where suppression has allowed unnatural understories of flammable, long-crowned conifers to develop beneath species such as red or white pine that were formerly protected from many crown fires by periodic underburnings. Prescribed fires could be used to reduce these ladder fuels. For red and white pine the feasibility of such prescribed fires was demonstrated in Minnesota 20 years ago by Dr. Robert Buckman.

The second and more general situation where prescribed fires may help is in restoring high-intensity fires in situations where we cannot now allow crown fires to roam because of safety constraints. What I visualize is prescription firing of stands located where fire control can be assured, even if crowning and rapid fire movement develop. By working with such natural barriers as lakes, streams, wetlands, nonflammable vegetation, rock fields, timberlines, snow fields, and so on, we may be able to burn significant areas safely. If such burns are well located, they might also facilitate moving into lightning fire management. What we must do is find <u>safe</u> means of restoring fire to these ecosystems. Fire managers must know their local situation intimately to carry out such burns successfully. But that is what professional park and wilderness management is all about.

The Dilemma Of Continuing Total Suppression Programs

Lest we close our minds to the possibilities of fire management in these ecosystems, we need to consider the alternatives! Given the nature of the forests and climates we are dealing with, the real choice is not whether we will have fire or no fire. It is really whether we will simply continue to react to wildfires under the worst possible fire control conditions--and still achieve considerable burned area but only after high suppression costs--or instead choose our fires according to a predetermined plan, achieve significant progress in restoring natural fire, and in the process become better equipped to deal with those wildfires that we must suppress for safety or other reasons. We should begin our programs cautiously, but <u>it is time to begin</u>! If we do not, we not only must continue major fire suppression programs with all their costs and impacts, but we will have condemned some of the world's most precious ecosystem reserves to an unnatural future.

A LOOK AT THE FUTURE

My assignment has been difficult. Nobody wants to advocate foolhardy programs, and yet even <u>thinking</u> about "managed" fire in some of these ecosystems may seem so. But the stakes are high. Restoring fire to its natural role in these ecosystems will require exceptional skill and professional dedication and substantial budgets. If we fail we will lose the natural landscape diversity of many of North America's most important and best-known national parks, wilderness areas, and related reserves. We may also lose our best chance to study and understand large-scale patterns and processes in many ecosystems--an understanding vital to preserving the natural diversity of the Earth (Romme and Knight 1982; Heinselman 1973, 1981b). Fortunately, we do have some time because fire suppression has not altered many of these ecosystems as much as it has those subject to frequent low-intensity fires, and in the far North, large areas still have essentially natural fire regimes. South of the high boreal region time <u>is</u> slowly running out.

We must look at the progress made in park and wilderness fire control technology and fire management to see where we have been and where we can go. Today we have helicopters, water bombers, retardants, aerial photographs, vegetation maps, sophisticated fuel models and fire danger assessment techniques, global weather monitoring, vastly better local weather forecasting, fire history research, a decade of experience with fire management, and even more with prescribed fires. We have already made impressive strides in Yellowstone National Park and several other areas where selected large high-intensity fires are being managed successfully. Yet less than 20 years ago fire management had not been seriously considered. It is difficult to say just which breakthroughs will make fire management a reality in most park and wilderness ecosystems subject to large stand-replacement fires, but I am confident we will make it happen! We must!

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245 IMPACT OF FIRE SUPPRESSION ON FOREST SUCCESSION AND FUEL ACCUMULATIONS IN LONG-FIRE-INTERVAL WILDERNESS HABITAT TYPES

James R. Habeck

ABSTRACT: Succession and fuel characteristics are described and discussed for a series of western redcedar (*Thuja plicata*) forests in the Selway-Bitterroot Wilderness, Idaho. Natural fire cycles in these moist forests are at 100- to 400-year intervals, and modern fire suppression may not have affected the cedar forests in this wilderness. The surrounding upland forests exhibit greater cover and fuel continuity and could threaten the long-fire-interval forest types; an operational wilderness fire plan, however, has led to the burning of thousands of upland acres during the past several years.

INTRODUCTION

In much of western North America the pristine landscape supported highly diverse vegetation types that varied floristically and in life forms. These plant communities are believed to have evolved in the presence of recurring fires. The western fire environment exhibits seasonal dry periods and ample opportunity for summer lightning ignitions. Major vegetation types include grasslands, deserts, sagebrush, pinon-juniper, chaparral, savanna, conifer forests, deciduous forest, timberline, and alpine. None of these western community types have completely escaped burning. The frequency of fire occurrence in these diverse types, however, varies greatly. Because of local or regional climatic patterns, topographic slope, aspect differences, and other factors, the expected or measured fire frequencies (number of years between burns) vary a hundredfold from one type to another. Wet, humid, and/or cool sites often support vegetation types that historically burned less often than those types occurring on sites that usually become warm and dry during the summer months (Larson 1919; Marshall 1928; Wellner, 1970; Kilgore 1981, 1982; Habeck and Mutch 1973).

The term "long-interval types," as used in this discussion, refers to those plant communities that usually experience fires at intervals between 50 to 100 years or less often--300 to 400 years. Many of these communities encompass the wet forests in the Pacific Northwest and portions of the Northern Rocky Mountains. In the Olympic Peninsula, for example, the western hemlock (*Tsuga heterophylla*), western redcedar (*Thuja plicata*), Sitka spruce (*Picea sitchensis*), and Douglas-fir (*Pseudotsuga menziesii*) forests occupying the wet west-facing slopes and the Hoh Valley burn infrequently, according to Agee and Scott (1983), and many of these coastal forest species have longevities of 500 to 700 years in the absence of fire.

The cedar-hemlock forests in Glacier National Park (northwestern Montana), northern Idaho, and elsewhere in the Pacific Northwest historically experienced destructive fires infrequently before 1900 (Kessell 1979; Habeck 1968, 1976a, 1976b; Arno and Davis 1980; Davis and others 1980). Similarly, the cedar-grand fir (*Abies grandis*) forests in the moist bottomlands and lower canyons of the Selway-Bitterroot Wilderness (Habeck 1976a, 1978) reach ages well over 400 years and sometimes over 600 years. Isolated lightning ignitions may completely burn out individual giant cedars in these summer-moist forests yet seldom cause widespread canopy destruction. Even the fires of 1910, which covered much of northern Idaho, had little impact on the ancient and impressive Moose Creek redcedar groves in the Selway-Bitterroot Wilderness. The spruce-fir/ timberline zones in the Pacific Northwest also support forests that historically experienced fire only at long intervals. These forests composed of *Picea engelmannii, Abies lasiocarpa, Pinus albicaulis, Tsuga mertensiana,* and *Larix lyallii* do not exhibit the same level of midsummer dryness shown by the short fire interval vegetation types and thus only occasionally burn extensively. When fire does occur, it may remain at a low intensity (in rocky or wet timberline sites), but the potential exists for it to become a high-intensity, stand replacement type of burn (Habeck 1976a; Fahnestock 1976; Despain and Sellers 1977; Davis and others 1980). This is also true of the subalpine forest communities in the western Wyoming-Yellowstone Park region as described by Romme and Knight (1981, 1983), where high-elevation fires are believed to operate on a 300-year cycle. When fires do visit these national park and wilderness forests, they are often high intensity, and lodgepole pine is thus perpetuated indefinitely.

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A wide assortment of forest types occurs in the Western United States and Canada; fire history studies indicate that these areas experienced fire only at long intervals during the presuppression era. The length of the interval is important because human intervention into natural burning cycles spans only a fraction of the time many of the long-interval types would have existed without being replaced by fire. The ecological impact of fire suppression on plant succession and fuel buildup within these forest types could be assessed as minimal during the past 50 to 80 years (Kilgore 1981); that is, whatever changes have occurred within these forests are primarily those that would have taken place anyway before modern fire suppression. Some of these natural changes are described and discussed in this paper, and a specific characterization of long-interval forest community composition, directions of succession, and documentation of fuel loading in the Selway-Bitterroot Wilderness' redcedar-grand fir forests are presented as an example. The discussion focuses on my personal experiences in this wilderness.

LONG-INTERVAL REDCEDAR FORESTS IN MONTANA

Western redcedar, along with its associated species, western hemlock, grand fir, and western white pine (θ†νξσ μουντ†≅ο}α), form distinctive communities in portions of western Montana and throughout much of northern Idaho. These conifers occupy those parts of the Northern Rockies that have the lowest moisture stress; these include moist river bottomlands and stream terraces. Where annual precipitation is high (over 25 inches/year [625 mm/yr]), cedar forest types also occupy lower mountain slopes.

Daubenmire and Daubenmire (1968) and Pfister and others (1977) have provided detailed descriptions and classifications of the redcedar forests in this region. Detailed fire ecology studies of these moist forest types have been published by Habeck (1968, 1976a, 1976b, 1980), Arno and Davis (1980), Larson (1929), Marshall (1928), Wellner (1970), Kessell (1979), and Davis and others (1980). Most of these authors agree on the low frequency of major fire events in the redcedar forests.

My investigations of redcedar-grand fir forests in the Selway-Bitterroot Wilderness occurred between 1971 and 1975; these studies were specifically aimed at relating forest compositions and fuel loadings to spatial and successional gradients. One-tenth-acre (≅0.04-ha) circular plots (relevés) were established in a manner that allowed sampling of the widest variation. Canopy coverage values (Daubenmire 1959) were recorded for all vascular plants in the plots. Fuels were inventoried using methods described by Brown (1974); these were measured only within the relevés. Between five and ten fuel plots were sampled in each. Personnel at the Northern Forest Fire Laboratory, Missoula, Mont., calculated fuel loading values.

In making these wilderness studies, I encountered the same difficulty--determining "stand age"--that is repeatedly reported by others doing similar research. In an attempt to relate successional development to time (chronosequential gradient), the need to know stand age, the time since it was last burned, or both, becomes important. Brown and See (1981) address the problem of establishing a stand's age when conducting fire ecology studies. In my studies, care was practiced in selecting homogeneous stands for plot placement, and I aged those trees that represented the most recent postfire entrants. Survivors of past fires were used primarily to provide insight into the site's fire history (fire frequencies, for example).

The sample plots and the data collected from them were ordered or stratified by habitat type classification and by direct and indirect gradient analysis (Habeck 1976a). These techniques permitted me to interpret the successional changes in the vegetation and evaluate the effects of forest development on fuel loadings.

SUCCESSIONAL CHANGES IN FOREST AND FUELS

For this analysis the samples were arranged on the basis of compositions and time since last burned. The stands occupied sites that ranged from mesic to wet; the wet bottomland cedar forests are often singularly dominated by *Thuja plicata* 4 to 6 ft (1.2 to 1.8 m) d.b.h., although *Abies grandis* is a common associate in many of the wilderness forests. In the very moist cedar communities (*Thuja plicata-Adiantum pedatum* and *Thuja-Asarum caudatum* habitat types) few stands less than 100 years old were encountered. The more mesic *Thuja-Clintonia uniflora* types sampled exhibit a range between 20 and 400 years. This group (15 stands) is discussed here in detail. In addition, two sets of contiguous, paired stands that were sampled (identical in all features except for last fire event) are discussed.

Table 1 summarizes my data from the *Thuja-Clintonia* samples. The stands are arranged by age, and the four trees encountered are listed by diameter (d.b.h.), size classes, and canopy coverage. The shrubs and ground-layer species are arranged to emphasize the compositional shifts that occur during postfire stand development. The pioneer ponderosa pine (*Pinus ponderosa*) and Douglas-fir (*Pseudotsuga menziesii*) become less dominant over time, and the potential climax species become, as expected, increasingly dominant in all size classes. The era of fire suppression has reduced creation of pioneer communities on the total wilderness landscape, but the impact in the moist cedar-grand fir stands has probably not been significant during the past five decades.

Table 1.--Successional changes within a series of *Thuja plicata-Clintonia uniflora* habitat type stands in the Selway-Bitterroot Wilderness, Idaho[1]

	Approximate stand age (years)														
	20	45	60	65	65	65	90	150	220	230	250	260	280	300	400
	[2]144	148	177	167	168	166	36	53	55	13	15	61	21	6	19
OVERSTORY															
Thuja plicata															
Over 12 in dbh	–	t	–	–	–	2	+	+	–	2	1	3	2	2	4
4-12 in dbh	–	–	–	–	t	2	3	1	1	–	3	1	3	+	1
Under 4 in dbh	t	t	+	2	2	2	t	1	1	–	+	–	–	+	–
Abies grandis															
Over 12 in dbh	–	–	1	–	–	–	1	1	1	4	+	1	2	4	2
4-12 in dbh	t	3	3	2	t	1	2	3	3	3	2	t	3	1	2
Under 4 in dbh	2	3	1	3	t	1	2	2	2	1	4	4	2	+	1
Pseudotsuga menziesii															
Over 12 in dbh	–	–	2	t	1	1	+	+	3	+	–	–	–	1	–
4-12 in dbh	–	2	1	2	3	1	1	1	2	–	–	–	–	–	–
Under 4 dbh	2	t	t	2	2	2	+	–	–	–	–	–	+	–	–
Pinus ponderosa															
Over 12 in dbh	–	–	–	+	–	–	–	–	+	+	–	2	–	–	–
4-12 in dbh	–	–	2	+	t	t	–	1	–	–	–	–	–	–	–
Under 4 in dbh	1	–	–	–	t	–	–	–	–	–	–	–	–	–	–
UNDERSTORY															
Apocynum androsaemifolium	t	t	t	–	–	–	–	–	–	–	–	–	–	–	–
Epilobium angustifolium	t	t	t	1	t	–	–	–	–	–	–	–	–	–	–
Ceanothus sanguineus	1	+	–	–	–	t	–	–	–	–	–	–	–	–	–
Holodiscus discolor	2	1	t	–	–	–	–	–	1	–	–	–	t	–	–
Amelanchier alnifolia	2	1	2	1	3	3	–	–	–	t	t	t	1	t	1
Rubus parviflorus	4	2	t	3	3	3	t	–	t	–	–	–	t	t	t
Vaccinium globulare	–	t	t	3	1	3	–	–	1	–	1	t	–	–	–
Lonicera utahensis	–	–	–	2	2	1	t	–	+	–	–	–	t	t	1
Acer glabrum	–	t	–	1	1	t	t	–	2	–	–	–	1	t	–
Galium triflorum	t	1	t	+	–	+	t	t	t	–	2	+	–	1	2
Smilacina stellata	t	t	1	–	–	1	–	t	t	t	2	2	t	t	2
Linnaea borealis	–	2	t	–	–	–	2	–	–	2	4	3	3	–	5
Adenocaulon bicolor	–	t	t	–	–	–	–	t	2	1	t	1	2	2	1
Clintonia uniflora	–	2	–	–	–	1	2	–	2	t	3	1	2	2	3
Coptis occidentalis	–	1	–	1	1	t	1	1	3	2	4	2	3	4	4
Viola orbiculata	–	–	–	–	t	–	–	t	–	2	2	2	–	1	1
Osmorhiza chilensis	–	–	–	–	–	–	t	–	1	t	1	t	t	1	1
Disporum hookeri	–	–	–	–	–	–	t	–	2	–	2	1	1	–	–
Cornus canadensis	–	–	–	–	–	–	–	–	–	t	1	1	1	t	2
Pedicularis racemosa	–	–	–	–	–	–	–	–	–	t	t	t	t	–	1
Xerophyllum tenax	–	–	–	–	–	–	–	–	+	–	t	1	t	t	–
Tiarella trifoliata	–	–	–	–	–	–	–	–	t	1	t	1	–	1	3
Menziesia ferruginea	–	–	–	–	–	–	–	–	–	–	–	–	1	+	2

[1]Stands have been arranged by stand age, reflecting time since last burned. Values are canopy coverage classes: t = trace; + = present in stand only.

[2]Stand numbers.

The ground-layer plants do show compositional shifts between the younger forests and the oldest. Some postburn pioneer species are still present in the 20- to 50-year-old forests; some species do not reappear until 50 or more years after burning. These are patterns of compositional change that have been described by Lyon and Stickney (1976), Stickney (1981), Crane and Habeck (1982), and Crane and others (1983) for other Montana and Idaho conifer forests. These other investigators have noted the year-to-year changes that are exhibited in permanent plots measured annually after burning. I was not able to document the changes taking place in the 1- to 20-year postfire period.

Table 2 summarizes fuel loading for each of the 15 stands. The fuel components do not show the relatively smooth, gradational shifts seen in table 1. Some of the larger branchwood fuels do show increases, but small fuel particles remain constant. Duff depths and weights do not correlate with stand age in these particular cedar forests; both young and old stands have low, intermediate, or high duff values. My upland stand samples (Habeck 1976a, 1976b) show a much better linear relationship between duff depth and time since last burned. Living forest biomass (standing crop) does increase over time (between fires). Rates of biomass accretion are typically high in young forests and diminish in the stands over 200 years old (Habeck 1976a, 1976b). The forest biomass that is measured as fuel, however, is only a fraction of the total standing crop. The centuries-old cedar stands support high biomass, but these generally have low assessed fire potentials (Brown and See 1981; Fischer 1981a, 1981b).

OTHER REDCEDAR FOREST COMMUNITY TYPES

The other long-fire interval cedar forests in the Selway-Bitterroot Wilderness, those within the *Thuja-Adiantum* habitat type and the *Thuja-Asarum* habitat types, are more moist and have even longer fire-free periods than the *Thuja-Clintonia* habitat type. The wilderness stands studied, however, do not include many that are less than a century old, and many are well over 300 years old; this makes a successional analysis difficult. It appears that the wetter cedar forests support a relatively high species diversity during the first century of postfire development, but diversity is reduced considerably after three or four centuries. The shrub layer becomes essentially lost, and only a few shade-tolerant herbs, ferns, and grasses persist in the oldest cedar groves. Modern fire exclusion does not seem to have significantly influenced the compositions of these old-growth cedar forests.

Fuel accumulations in the wetter cedar stands follow the same basic pattern as *Thuja-Clintonia* stand samples (table 2), except the total fuel loading weights may reach values up to 160 tons/acre (395 tons/ha). About 40 percent of such high loadings is composed of large-diameter, downed stems, and another 50 percent is represented in deep duff layers of approximately 3 to 4 inches (3.7 to 10 cm). The proportion of downed, woody stems (4 to 6 ft in diameter [1.2 to 1.8 m] in decaying condition is very high in the typical wilderness cedar grove. No doubt wildfire would add to the fuel load in these cedar stands, but examples that would demonstrate this were rarely encountered. Estimates based on informal

Table 2.--Fuel loading characteristics within a series of *Thuja/Clintonia* habitat type stands in the Selway-Bitterroot Wilderness, Idaho.

Stand No.	Stand age	Fuel categories 0.25.09 inches	1.0-3.0 inches	Over 3 inches sound	Over 3 inches rotten	Litter	Duff fuel	Total loading	Duff depth
	Years	Tons/acre							Inches
144	20	0.4	0.3	0.0	0.0	0.1	32.0	35.0	1.6
148	45	.3	.8	.0	.0	.2	42.0	43.0	2.1
177	60	.2	.0	.0	.0	.2	19.0	20.0	.9
167	65	.3	2.2	.0	1.6	.2	43.0	48.0	2.1
168	65	.2	.0	.0	2.1	.2	37.0	41.0	1.8
166	65	.5	.0	4.6	.0	.2	33.0	40.0	1.7
36	90	.1	.9	.2	.0	.3	9.0	10.0	.6
53	150	.2	1.8	.1	.4	.4	28.0	30.0	1.5
55	220	.2	.9	.3	1.1	.4	21.0	23.0	1.4
13	230	.1	.7	3.8	.8	.3	31.0	37.0	1.6
15	250	.2	.7	29.0	67.0	.3	38.0	135.0	2.0
61	260	.1	.6	.1	.1	.4	40.0	42.0	1.8
21	280	.2	.9	10.0	40.0	.4	39.0	91.0	1.9
6	300	.1	.8	11.0	.0	.2	34.0	47.0	1.8
19	400	.2	.7	8.3	92.0	.3	43.0	144.0	2.2

transect counts suggest that the wet cedar forests support 5 to 8 isolated burned cedar snags per acre (≅2 to 3 per ha) this represents a long-term accumulation of lightning ignitions within the cedar groves that failed to spread beyond a single tree.

PAIRED STAND ANALYSIS

Further elucidation of the role of fire, or its absence, on conifer forest composition and fuel loadings in the Selway-Bitterroot Wilderness is provided in table 3. Here two sets of paired

Table 3.--Comparison of structural and compositional features of paired *Abies grandis* stands (126 and 127) and paired *Thuja plicata* stands (184 and 185)[1]

	Stand pairs			
	Abies grandis series		*Thuja plicata* series	
Stand features	126	127	184	185
Time since last fire	15 years	215 years	35 years	185 years
Elevation	803 m (2,650 ft)	803 m (2 650 ft)	1 060 m (3 500 ft)	1 060 m (3,500 ft)
Aspect/slope	E/5°	E/5°	Level	Level
TREE COMPOSITION[2]	Cover class			
Pinus ponderosa	0-0-4	3-0-0	None	None
Pseudotsuga menziesii	0-0-2	0-2-+	0-0-2	None
Abies grandis	0-0-2	0-4-2	0-2-2	2-3-2
Pinus monticola	None	None	0-1-1	None
Pinus contorta	None	None	0-2-2	None
Thuja plicata	None	None	0-0-T	3-T-2
UNDERSTORY SHRUB DOMINANTS				
Holodiscus discolor	4	2	-	-
Ceanothus sanguineus	3	T	-	-
Philadelphus lewisii	3	1	-	-
Rhamnus purshiana	2	-	-	-
Vaccinium caespitosum	-	-	3	-
Pachistima myrsinites	-	-	3	1
Vaccinium globulare	-	-	T	2
UNDERSTORY FORB DOMINANTS				
Centaurea maculosa	3	-	-	-
Trifolium repens	4	T	-	-
Hypericum perforatum	3	-	-	-
Epilobium angustifolium	2	-	-	-
Iliamna rivularis	1	-	-	-
Clintonia uniflora	-	2	1	3
Coptis occidentalis	-	2	T	3
Arnica cordifolia	-	2	-	-
Linnaea borealis	-	-	T	2
Xerophyllum tenax	-	-	4	1

[1]Cover classes (Daubenmire 1959) are given for trees within three diameter size classes and for dominant understory shrubs and forbs. Stands 126 and 127 are classified *Abies grandis/Clintonia uniflora* habitat types; stands 184 and 185 as *Thuja plicata/Asarum caudatum* habitat types.

[2]In the three-digit set, the value to the left is cover class for trees over 12 inches (3 dm) d.b.h.; center value is cover class for trees 4 to 12 inches (1 to 3 dm) d.b.h.; and third digit is for trees under 4 inches (1 dm) d.b.h. T = Trace; + = present only.

stands are compared; one set, stands 126 and 127, represent the *Abies grandis-Clintonia uniflora* habitat type, and the second pair, stands 184 and 185, a moist *Thuja plicata-Asarum caudatum* habitat type. The stands in each pair occupy similar sites, but the length of time since last burned differs. Both overstory and understory dominants are compared using canopy coverage values. Standard fuel loading data (table 4) are also provided for these paired stands.

In the young (15-year-old) grand fir stand (126), pioneer plant species dominate the site, although the potential climax tree, grand fir, is already well represented. In the adjacent 215-year-old stand (127), compositional differences are pronounced: grand fir continues to reproduce well; the shrubs, so dominant in the pioneer stand, are much diminished in the climax stand. Similar comments can be made about the herbaceous layer. Disturbance species dominate the young forest but do not appear in the older stand. In comparing these two grand fir forests on the basis of their fuel loadings, we see that the total load is double in the older stand. It appears that only a portion of stand 126's duff layer was burned off during the fire treatment it received, and thus duff fuels still contribute significantly to the total loading. Neither stand has large-diameter branchwood fuels (over 3 inches [7.6 cm]). There is a big difference in the shrub fuel loadings, however; a six-fold reduction exists between the younger and older stand.

The paired *Thuja plicata* stands, one 35 (184) and the other 185 years old (185), reveal similar shifts in their compositions and fuel loadings. The younger stand is dominated by a mixture of pioneer and climax trees, whereas only cedar and grand fir still survive in the older stand. Coverage values for shrubs and herbaceous species shift between pioneer and climax shrub stages in a pattern similar to that noted for the first pair of stands, although the shrub diversity and cover are less than in grand fir stands. The changes in the fuel loadings in this second set of paired stands also shift upward, although the cedar forests have higher amounts of over-3-inch (7.6 cm) downed, woody materials. In both sets of paired stands, duff fuels represent 80 percent to over 90 percent of the total load. The older cedar stand barely has a shrub fuel layer.

ESTIMATED FIRE BEHAVIOR

All of the forests studied in the Selway-Bitterroot Wilderness were subjected to an assessment of fire behavior in terms of estimated fire spread rates and fire intensities; the techniques described by Rothermel (1972) and Albini (1976) were applied. A more recent treatment of fire behavior in redcedar forest types has been published in the form of a photographic guide by Fischer (1981a, 1981b).

Assuming 5 percent fuel moisture, a 5 mph (8.3 kmph) wind, and level terrain, the cedar stands have predicted fire spread rates that fall between 5 and 10 ft (1.5 and 3.0 m) per minute (range 1 to 15 ft/min; 0.3 to 4.5 m/min); seral communities between 50 and 100 years old average less than 3 ft/min (1.0 m/min) (range 0.5 ft/min; 0.2 to 1.5 m/min); and old-growth cedar averages less than 1.5 ft/min (0.4 m/min) (range 0.25 to 2.5 ft/min; 0.07 to 0.75 m/min). Estimated fire intensities (Byram's Intensity, expressed in BTU's/s/ft) drop considerably between pioneer early seral climax stages of succession; they range from an average of 16.5 BTU's/s/ft (range 3 to 60) in the early development stages down to an average of only 2.7 BTU's/s/ft (range 0.5 to 7) in the 300- to 500-year-old cedar groves. Fischer's evaluation (1981a, 1981b) considers fire intensities and rate of spread on an "average bad day" (high temperatures, moderate wind, low humidity, and summer drought), and mature redcedar forests are rated only low to medium in fire potential, confirming my interpretations. The fire spread rates and levels of fire intensity in the paired stands (table 4) indicate higher values in each of the younger stands, with the young grand fir forest having the highest fire potential.

Table 4.--Comparison of fuel loading characteristics within two sets of paired stands described in table 3

	Fuel categories									
Stand No.	0.25.09 inches	1.0-3.0 inches	Over 3 inches sound	Over 3 inches rotten	Litter	Duff fuel	Total loading	Duff depth	Fire spread rate	Fire intensity
	Tons/acre							Inches	Ft/min	BTU/s/ft
Abies grandis/Clintonia										
126	0.4	0.6	0.0	1.6	0.2	30.0	32.0	1.5	6.6	12.1
127	1.3	1.5	.0	1.6	.5	59.0	64.0	3.0	.9	1.5
Thuja plicata/Asarum										
184	.8	1.5	5.0	.0	.3	21.0	30.0	1.5	.9	3.4
185	.4	.8	10.5	2.9	.3	66.0	81.0	3.4	.7	1.0

CONCLUDING INTERPRETATIONS

Forest types that are known to have long fire-free intervals do accumulate biomass between fires; it has become accepted that in many parts of the Pacific Northwest and the Northern Rockies the rate of productivity is higher than the rate of decomposition, which leads to a net annual increment in standing crop. Forests that occupy cool and moist zones may have fire-free intervals of between 100 and 400 years. It is likely that some special combination of factors must coincide in order for these long-fire-interval types to experience a high-intensity, stand replacement fire. Such coincidences do occur at a low frequency, and it is possible to encounter examples where ancient cedar groves or centuries-old spruce-fir, lodgepole pine, or both have been replaced through the action of past, high-intensity wildfires. In the context of this wilderness fire conference's theme relating to fuel buildups, it can be concluded that long-interval forest types, a century old or older, have not changed much in their fuel loadings during the 50 to 80 years of fire suppression. Natural successional changes do involve biomass increments, but among the redcedar forests in the Selway-Bitterroot Wilderness, much of the increase in biomass is represented in living standing crop and in very large, rotting, downed stems that do not enhance the wildfire potential.

The long-fire-interval types in the Selway-Bitterroot Wilderness, however, are completely surrounded by forest types that have much shorter natural fire-free intervals (adjacent types in the Douglas-fir and ponderosa pine zones). Examination of the large-scale wilderness landscape patterns (aerial photos dating from the 1930's to the present) reveals that the past half-century's efforts to suppress wildfires has created an unnatural forest cover continuity that may not have existed in times past (see Kilgore 1981 and 1982 for elaboration). The redcedar groves in the Selway River drainage can be viewed as being in greater fire danger now than in the past because of the continuous green forest carpet developing around them. The protection afforded them in the past, in the form of forest discontinuities on adjacent uplands, has been lost. My studies show that when redcedar forests are examined as isolated pieces of vegetation occupying cool, moist, lowland sites, the impact of modern fire management has been minimal. When placed within the total wilderness landscape, however, these long-interval types have been placed in a precarious position as a result of modern fire suppression; indeed, if the adjacent upland forests were still burning at presuppression intervals, the cedar forests could be expected to maintain their long-fire-interval status. The loss of the vegetation mosaic (or fuel discontinuities) in the Selway-Bitterroot Wilderness is currently being mitigated through implementation of a fire management plan (Keown 1978); during the past five fire seasons nearly 40,000 acres (16 000 ha) of wilderness have been allowed to burn with minimum control. This unquestionably will benefit the long-fire-interval forest types.

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FIRE SUPPRESSION EFFECTS ON FUELS AND SUCCESSION IN SHORT-FIRE-INTERVAL WILDERNESS ECOSYSTEMS

Jan W. van Wagtendonk

ABSTRACT: Fire is a dominant force in short-fire-interval wilderness ecosystems. A computer simulation model of these ecosystems was developed that combines vegetation, fuel, weather, and lightning to simulate fires that then interact with vegetation and fuel. The model predicts the effects of no-fire, lightning-fire, and suppression scenarios on fuel energy, basal area, and density by species. For Sierra Nevada mixed conifer ecosystems, the no-fire scenario allows fuels to accumulate and white fir to replace ponderosa pine. Lightning fires keep fuel levels low and favor ponderosa pine. The model can be used to design prescribed fire programs to reintroduce fire into wilderness ecosystems and to understand the role of fire in those ecosystems.

INTRODUCTION

The concept of a wilderness ecosystem includes the effects of natural processes. In fact, the Wilderness Act specifically defines wilderness as an area that "generally appears to have been affected primarily by the forces of nature." Certainly, fire is one of those forces.

When wilderness areas were first established, the concept of suppressing all fire was still prevalent. Not until 1972, in the Selway-Bitterroot Wilderness, however, was a lightning fire allowed to run its course within a prescribed management zone in wilderness (Mutch 1974). Previous to that, lightning fires were allowed to burn under prescribed conditions in backcountry areas of Everglades, Yosemite, and Sequoia and Kings Canyon National Parks and in Saguaro National Monument (Kilgore 1983). The rationale for establishing those programs was that fire had been a part of each ecosystem for eons and that its exclusion had led to unnaturally high fuel accumulations and shifts in plant succession. Research studies had shown that this was particularly true in ecosystems that had evolved with frequent low-intensity fires such as ponderosa pine (*Pinus ponderosa*) and giant sequoia-mixed conifer forests (Weaver 1959; Cooper 1960; Hartesvelt 1964; Biswell 1967). Although these and subsequent studies documented the effects of fire suppression on fuels and succession and described the processes that led to the altered conditions, few were able to relate fire frequency and intensity directly to long-term ecological changes (Kilgore 1981).

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Two studies have attempted to define this relationship. In the first study (van Wagtendonk 1972) I used a computer model called FYRCYCL to simulate fuel accumulations, lightning fires, and subsequent fuel reductions. Bonnicksen and Stone (1982) developed a structural model that predicts age, number of vertical layers, and species composition of tree aggregations. A major shortcoming of my model (1972) was that it did not include a vegetation subroutine. Consequently, the effects of fire on succession and on subsequent fuel accumulation were not considered. On the other hand, the Bonnicksen and Stone (1982) model did not produce fire frequencies and intensities.

For land managers to reintroduce fire into wilderness ecosystems, it will be necessary to know what the natural fire regime is and what its effects are on fuel accumulations, stand structure, and species composition. Only then can we begin to use fire as a tool to simulate fire in its natural role.

SHORT-FIRE-INTERVAL ECOSYSTEMS

The role of fire in ponderosa pine ecosystems has been described by Kilgore (1981). The process starts with the germination of seeds in openings created by the death of overstory trees by insects, disease, lightning, windthrow, or an occasional crown fire. The seeds come from trees adjoining the opening and germinate on an ash seedbed prepared by the fires that burned the dead trees. The small accumulations of needles underneath the young pines do not carry a fire and thus protect them until they are able to survive. Subsequent fires remove any small trees underneath the large trees. In such ecosystems, fire suppression allows fuels to accumulate and small trees to increase in the understory until a fire exceeding the suppression capability occurs and the entire stand burns.

The process in mixed conifer ecosystems is similar except that additional species are present. In these forests an understory of shade-tolerant species develops in the absence of fire. These species include white fir (*Abies concolor*) and blue spruce (*Picea glauca*) in the Southwest, white fir and incense-cedar (*Libocedrus decurrens*) in California, and grand fir (*Abies grandis*) in the Intermountain West. Douglas-fir (*Pseudotsuga menziesii*) is an overstory associate of ponderosa pine throughout the type except in the southern Sierra Nevada, where sugar pine (*Pinus lambertiana*) becomes more common and where occasional groves of giant sequoias (*Sequoiadendron giganteum*) occur.

The fire process in mixed conifer ecosystems is similar to that in ponderosa pine systems (Kilgore 1981). Periodic fires eliminate most of the shade-tolerant understory that develops between fires favoring the more fire-tolerant pines. Local variations in fire intensity create openings in the forest, which would become regenerated with all available species except that survival varies amongst species with the ability of each species to grow under various levels of sunlight, litter depth, and fire intensity. For instance, giant sequoia seedlings require mineral soil for germination, a condition that would only occur with a locally intense fire.

The effects of fire suppression in mixed conifer forests have been an increase in fuel accumulation and a shift in composition toward shade-tolerant species. These changes have increased the potential for a high-intensity crown fire, not only by providing more available energy but also by creating pathways for flames to reach the overstory canopies. Such crown fires usually exceed the capacity of suppression forces.

MODELING SHORT-FIRE-INTERVAL ECOSYSTEMS

The questions of fire frequency and intensity are basic to understanding fire's role in wilderness ecosystems with short fire intervals. Computer modeling is one tool that can be used to answer those questions as well as give insight into the behavior of the system. Such a model should use independent inputs to generate fires, include the effects of fires on fuel and vegetation, and provide data on the fire regime, fuel accumulations, and stand structure and composition. In addition, the model should be able to show the effects of various management strategies. For instance, the results from a no-fire scenario must be compared to results from suppression and lightning-fire scenarios. Agee (1973) felt that the FYRCYCL model was potentially most adaptable and could provide the basis for an improved fire model in mixed conifer ecosystems.

The original FYRCYCL model included subsystems that accumulated an annual fuel increment and decomposed fuel at a given rate. A lightning subsystem produced thunderstorms, lightning strikes, and strike locations. Air temperature, relative humidity, 10-hour time lag fuel moisture, and windspeed were generated by a weather subsystem. The fire subsystem combined outputs from other subsystems to produce or not produce a fire of a given intensity that then reduced fuels. The model has been modified to include vegetation growth and mortality subsystems for a mixed conifer ecosystem. The species included in those subsystems are ponderosa pine, sugar pine, white fir, and incense-cedar.

Figure 1 depicts the interactions of the various subsystems. The model starts with an input of seedlings to the vegetation growth subroutine. As the trees grow, fuel begins to accumulate. Some mortality also occurs as trees begin to compete

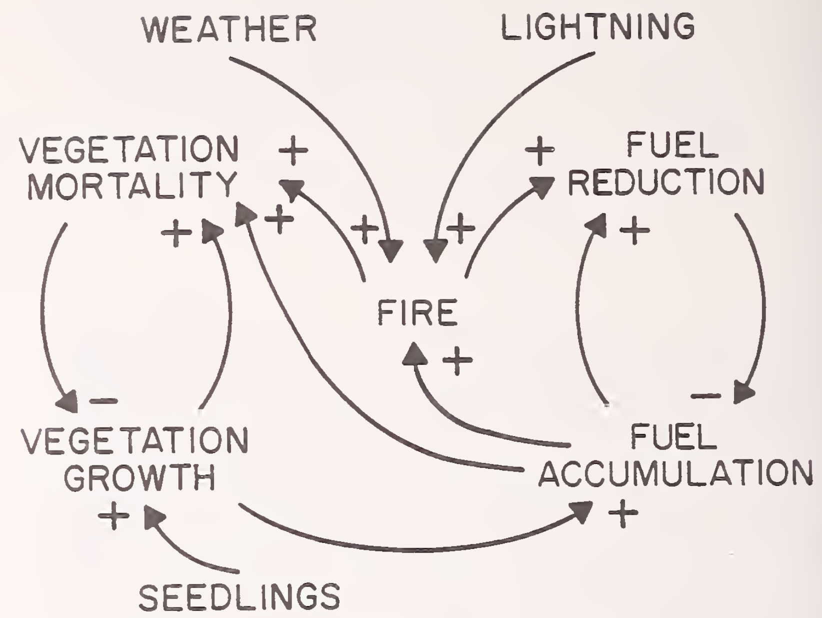

Figure 1.--Major subsystems of the FYRCYCL model. Sign indicates the nature of the relationship between subsystems.

with each other for light, moisture, and space. Increased fuel accumulation increases the energy available for a fire and the amount of fuel available for decomposition. Deep fuels also increase mortality by inhibiting seedling germination and growth. The simultaneous occurrence of favorable weather, a lightning strike, and adequate fuel generates a fire that reduces fuels and increases tree mortality. Finally, increased mortality decreases growth.

Vegetation Growth

The vegetation growth subsystem calculates new basal areas and densities for each species and age. The subsystem inputs are the total number of new seedlings, the basal area of a single seedling of each species, and the proportion of the total basal area attributed to each species. Basal areas were determined from field studies in Yosemite that related height to age and to diameter at breast height. After the initial pass, the number of trees of each age and species is set equal to the number present at the end of the previous year. New trees are generated by applying basal area percentages by species from the previous year to the constant seedling input.

Fuel Accumulation And Decomposition

Each year a new layer of fuel is deposited on the forest floor in the form of needles and woody branches. The amount of each year's increment depends on the basal area of each species and was determined from field studies in Yosemite National Park. Heat yield values from Agee and others (1978) were used to derive the annual accumulation of fuel energy.

The decomposition routines are identical to those in van Wagtendonk (1972), which were based on earlier work by Jenny and others (1949). Outputs from this subsystem are the total amount of fuel energy on the ground at the beginning of the year and the depth of that fuel. Regression equations developed by Agee (1973) were used to determine fuel depth.

Lightning

The number of lightning strikes per month was calculated from thunderstorm activity levels using a Poisson distribution. Because not all lightning strikes are potential fire starters, the total number of strikes was multiplied by 0.25 to reflect the number that actually ignite fires (Arnold 1964). The location of the lightning strike relative to the area of concern determines the spread direction. Data from Komarek (1967) were used to determine the probability of a strike hitting a ridgetop or the upper, middle, or lower third of the slope.

Weather

Hull and others (1966) evaluated critical fire weather patterns associated with synoptic weather types. These data, which included data from a station in the Sierra Nevada, were used to determine the probability of a weather type in a given month. For each month and weather type, minimum, maximum, quantile, and mean values were listed for air temperature, relative humidity, 10-hour time lag fuel moisture, and windspeed. These values were used to construct cumulative frequency tables based on a normal distribution. Specific values for the four weather variables make up the output from this subsystem.

Fire

When a lightning strike occurs, the fire subsystem is called. Inputs to it include spread direction, total fuel energy and weather variable values. Based on data from van Wagtendonk (1972) and Rothermel and Anderson (1966) rate of spread, fire line intensity, heat per unit area, and flame length are calculated as functions of the input variables.

Fires that burned with intensities less than 100 Btu/ft/s were classified as surface fires. For more intense fires, energy criteria were used to determine if the fire remained on the surface and burned understory fuels or if it reached crown fire potential. That point is recognized when the energy generated by the fire exceeds the energy in the wind environment (Davis 1959).

Fuel Reduction

Fuel reduction is calculated by subtracting the heat per unit area from the total fuel energy per unit area. For understory fires, 75 percent of the surface fuels were said to be consumed, whereas crown fires burned all surface fuels.

Vegetation Mortality

Four mortality factors are considered in this subsystem. The first is mortality caused by the fire. In a 1983 study, I related this factor to flame length in understory trees less than 20 ft (≅6 m) high (van Wagtendonk 1983). The equations I derived were capable of predicting the tree height that would experience 50 percent mortality given the flame length for each of the four mixed conifer species. For all trees, mortality was 100 percent if the scorch height as calculated by Van Wagner (1973) exceeded the tree height.

Mortality caused by shade and duff depth mortality were determined from data on natural regeneration after logging in the Sierra Nevada (Stark 1965). Duff depth was obtained from the fuel accumulation subroutine, and shade was drived from total basal area and the percentage of small-crowned trees (Wellner 1948).

Mortality other than that caused by fire, shade, or duff depth was termed normal mortality. It was calculated from data collected in the field and from numerous sources in the literature that related number of trees to height. Equations developed from these data predict the normal percentage reduction in numbers of trees from year to year.

All of those factors were applied to the tree numbers generated by the vegetation growth subsystem to provide new basal area, percent basal area, and density by species.

Suppression Capability

At the beginning of each run it is possible to specify the suppression capability in terms of the intensity the suppression force could contain. Setting the capability at zero would produce the lightning fire regime without suppression, whereas a high capability (100,000 Btu/ft/s) would produce results for a system without fire. Fire suppression scenarios can set the capability at any level between these extremes, depending on the suppression force available.

Prescribed Burning

The model also has the capability of running various prescribed burning scenarios. For instance, it is possible to specify the number of years from the beginning of the run to the start of a prescribed burning program. This feature would model the initiation of prescribed burning after a specific period of successful suppression. Other options include specifying the number years between fires, the burning direction, the months during which prescribed burning would be accomplished, and a desired level of fuel energy accumulation indicating the point when the prescribed burning program would end.

SIMULATION RESULTS

Initial model runs tested the validity of the model and input data. Historical fire records and field data were compared to model results to determine their reasonableness. This process often led to closer investigation of the model to find sources of error or erroneous assumptions. After testing was completed, repeated runs were made to incorporate random variation. All runs had identical initial conditions and ran for 200 years.

The first scenario simulated a no-fire situation. From these runs it was possible to show the effects of having all fires eliminated from the ecosystem. A lightning-fire regime was simulated with the second scenario. The third scenario assumed a suppression capacity of up to 1,000 Btu/ft/s, a level considered by Roussopolous and Johnson (1975) to be at the limits of control. Finally, a scenario was run that simulated prescribed burning after a 94-year period of successful fire suppression. Results from these scenarios are discussed as they affect fire behavior, fuel accumulation, and vegetation succession.

Fire Behavior

The mean fire interval for lightning fires was 8.9 years, with surface fires occurring every 10.2 years and understory fires every 50.3 years. This interval corresponds closely with the 9.2-year interval for southwest-facing slopes of a mixed-conifer forest in Kings Canyon National Park (Kilgore and Taylor 1979) and the 8- to 10-year interval for the central Sierra Nevada (Wagener 1961). The first fire did not occur until after 34 years.

Table 1 shows values for intensity, rate of spread, heat per unit of area, and flame length that occurred for 22 fires from a typical run. Fire line intensities averaged 91.8 Btu/ft/s; backing fires averaged 23.6 Btu/ft/s and head fires, 160.1 Btu/ft/s. The most intense fire (777.1 Btu/ft/s) burned during July.

Only two fires occurred during the suppression scenario. Both were crowning head fires burning in June and July. The first one burned after 135 years of successful suppression efforts. It had an intensity of 1,609.3 Btu/ft/s with corresponding flame length at 13.4 ft. Its rate of spread was 2.0 ft/min, and it burned 14,538.8 Btu/ft^2 of fuel. The second fire was less intense at 1,240.6 Btu/ft/s but spread at 2.2 ft/min. The flame length was 11.9 ft and the heat per unit was 10,174.0 Btu/ft^2.

Fuel Effects

The accumulations of fuel under the no-fire, lightning-fire, and suppression scenarios are shown in figure 2. In each scenario, fuels start to build up slowly until the basal area is sufficient to produce significant amounts of fuel. Without fires the accumulation increases to a maximum of 13,000 Btu/ft^2 at 114 years. After that point fuel decreases because the basal area of the more prolific fuel-producing pines has started to decrease while white fir basal area has been rising. Decomposition exceeds the reduced accumulation but would reach an equilibrium after several more years. The average accumulation without fire was 9,511 Btu/ft^2.

Table 1.--Fire behavior for 22 simulated lightning fires during a 200-year run

Year	Intensity	Rate of spread	Heat/area	Flame length
	Btu/ft/s	Ft/min	Btu/ft^2	Ft
34	24.3	0.6	2,602.6	2.0
41	21.6	.5	2,437.5	1.8
47	29.6	.8	2,275.7	2.1
52	39.2	1.1	2,063.4	2.4
59	63.3	3.8	1,000.5	3.0
65	35.9	.8	2,720.0	2.3
72	21.8	.5	2,422.6	1.9
82	57.6	3.6	954.7	2.9
88	25.4	.5	2,965.9	2.0
97	777.1	7.4	6,341.0	9.6
100	471.5	6.9	4,090.8	7.6
111	58.5	3.6	962.3	2.9
116	84.1	4.4	1,153.0	3.5
133	22.4	.5	2,449.7	1.9
144	22.2	.4	2,889.2	1.8
153	22.2	.4	3,042.0	1.9
162	42.2	.8	3,202.8	2.5
167	102.1	4.8	1,269.6	3.8
175	24.7	.5	2,930.7	2.0
181	23.8	.6	2,495.2	1.9
193	29.2	.5	3,263.2	2.1
198	24.3	.6	2,592.6	2.0

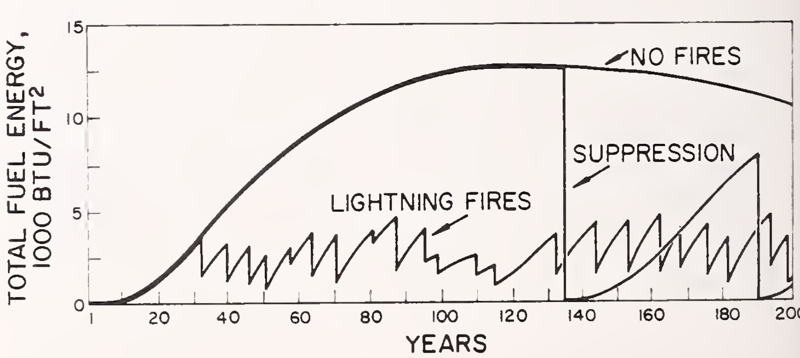

Figure 2.--Total fuel energy accumulation under no-fire, lightning-fire, and suppression scenarios for 200-years runs of the FYRCYCL model.

Fuels continued to build up under the lightning-fire scenario until the first fire occurred during the 34th year. Until that time insufficient fuel had accumulated to sustain a fire in given weather and lightning probabilities.

Subsequent fires kept the accumulation down to an average of 2,495 Btu/ft^2. The lowest level reached was after the 52d year when a fire reduced a 4-year accumulation down to 849 Btu/ft^2. The maximum accumulation was in year 193 after a fire-free interval of 11 years. Although there were longer intervals, by this time the stand was almost pure ponderosa pine near its maximum basal area.

The fuel accumulation for the suppression scenario followed the no-fire rate until the first crown fire reduced it to zero. The subsequent buildup was more rapid, however, because the surviving proportion of ponderosa pines was greater than it had been under initial conditions. The second crown fire also reduced fuels to zero.

Vegetation Effects

The effects of the three scenarios on basal area percentage and density are shown for each species in figures 3 and 4. Initially, ponderosa pine is able to increase its proportion of the basal area because it grows faster and is able to survive best in open conditions with shallow litter. As the stand becomes denser and white fir proliferates and grows, a shift in basal area percentage occurs. In the 155th year, white fir finally overtakes ponderosa pine. Sugar pine and incense-cedar remain minor participants in the shift because they are intermediate in their shade tolerance (Baker 1949). The density distribution without fire follows the same pattern. The apparent aberrations between years 107 and 127 are caused by changes in the shade and litter mortality factors that are near boundary values for those factors.

The lightning-fire scenario increases the basal area percentage for ponderosa pine at the expense of white fir. Small fluctuations occur as the fires eliminate trees. The density plot dramatically shows the effects of fire on each species. Because of its initial survival and growth advantage and its subsequent higher fire tolerance, ponderosa pine is able to dominate the ecosystem.

The two crown fires from the suppression scenario reduce basal area and density to nearly zero. A few individuals of each species survive, but ponderosa pine survivors are the largest and most numerous.

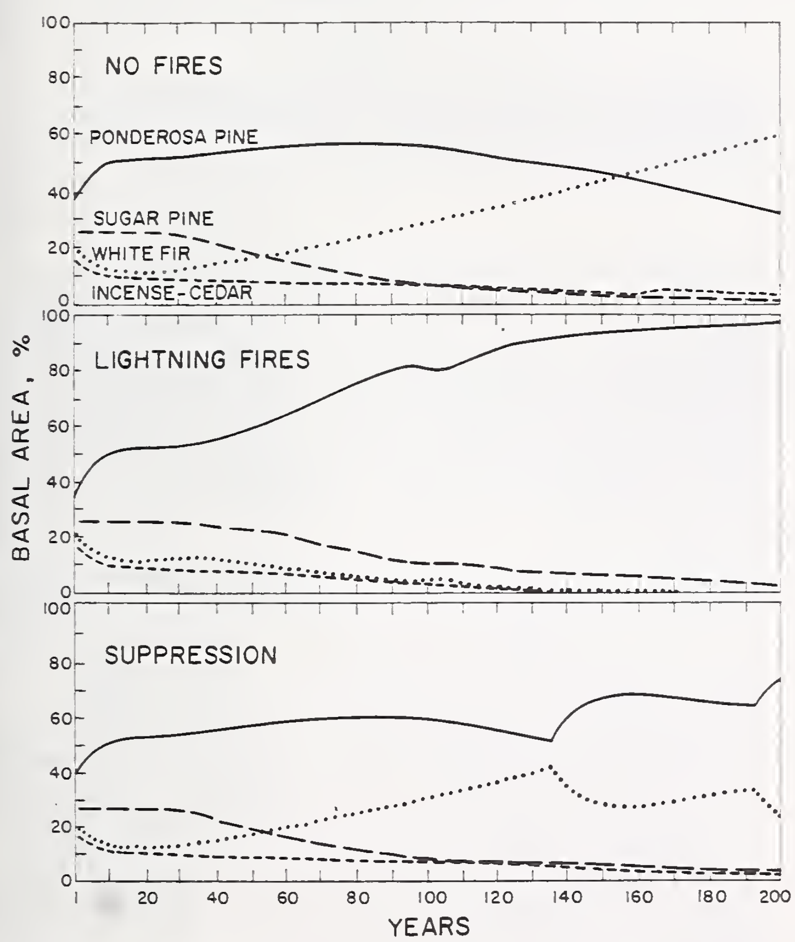

Figure 3.--Percent basal area effects under no-fire, lightning-fire, and suppression scenarios for 200-year runs of the FYRCYCL model.

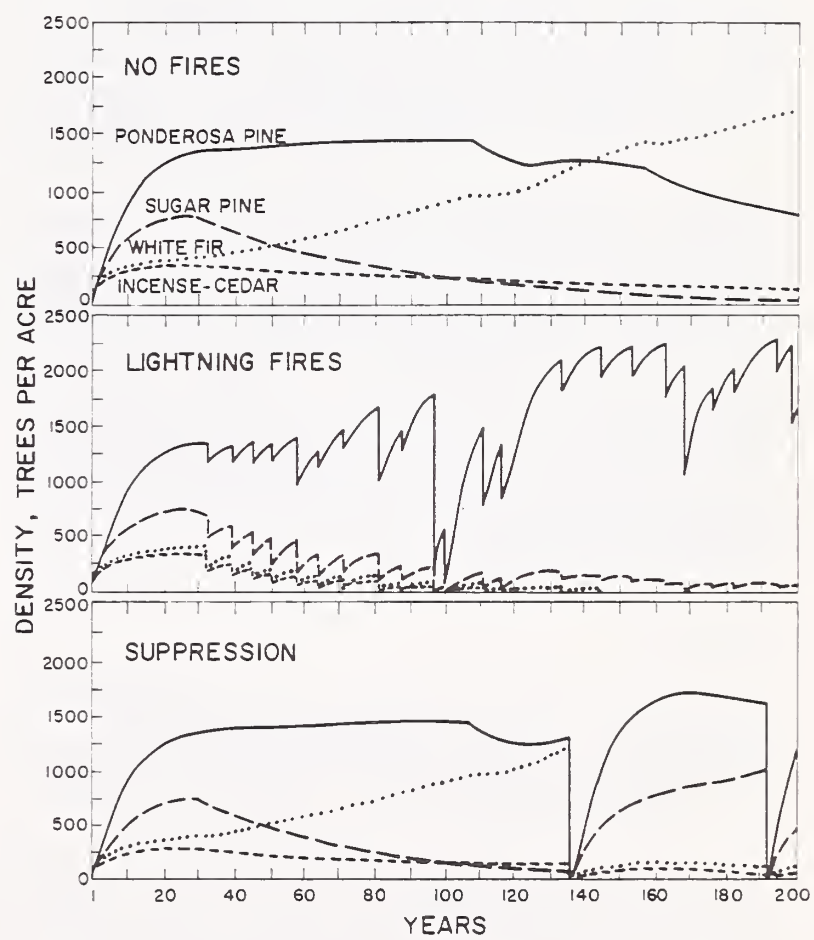

Figure 4.--Density effects under no-fire, lightning-fire, and suppression scenarios for 200-year runs of the FYRCYCL model.

Effects Of Prescribed Fires

Prescribed burns were simulated to reduce fuel accumulations resulting from suppression. The burning program was initiated after 94 years of suppression to indicate what might happen if suppression efforts had been in effect since 1890. Burning was done every 8 years until the fuel accumulation was reduced to 3,500 Btu/ft^2. Strip head fires were prescribed unless the estimated intensity exceeded 120 Btu/ft/s when backing fires were used. Burning was to be done under the first set of favorable weather conditions during the months of April, May, September, or October.

Four prescribed burns were required over a period of 27 years to bring the fuel accumulation down to the desired level. The first two were head fires that burned during September, the third a backing fire during October, and the last an April head fire. The intensities ranged from 47.1 Btu/ft/s for the October fire to 117.1 Btu/ft/s for the April fire. Rates of spread ranged from 0.5 ft/min to 5.2 ft/min, and flame lengths were 2.5 ft and 4.0 ft for the same two fires.

The first lighting fire occurred during the 1125th year. Subsequent fires had a mean fire interval of 5.9 years. The most intense fire was 77.4 Btu/ft/s and burned 24 years after prescribed burning ended.

The effects of the prescribed fire scenario on fuels, basal area percentage, and density are shown in figure 5. The fuel builds up to 12,247 Btu/ft^2, and the four prescribed burns reduce it to 3,477 Btu/ft^2. After that lightning fires keep the fuel down to an average of 2,687 Btu/ft^2.

The basal area percentage graph shows ponderosa pine increasing until the 78th year, when white fir starts to exert its influence. The prescribed fires reinstate ponderosa pine, and it continues to increase its percentage through the prescribed and lightning fire regimes.

The dominance of ponderosa pine after prescribed fire is introduced is vividly shown in the density graph. As ponderosa pine increases in number with each fire, the other species subside and practically disappear.

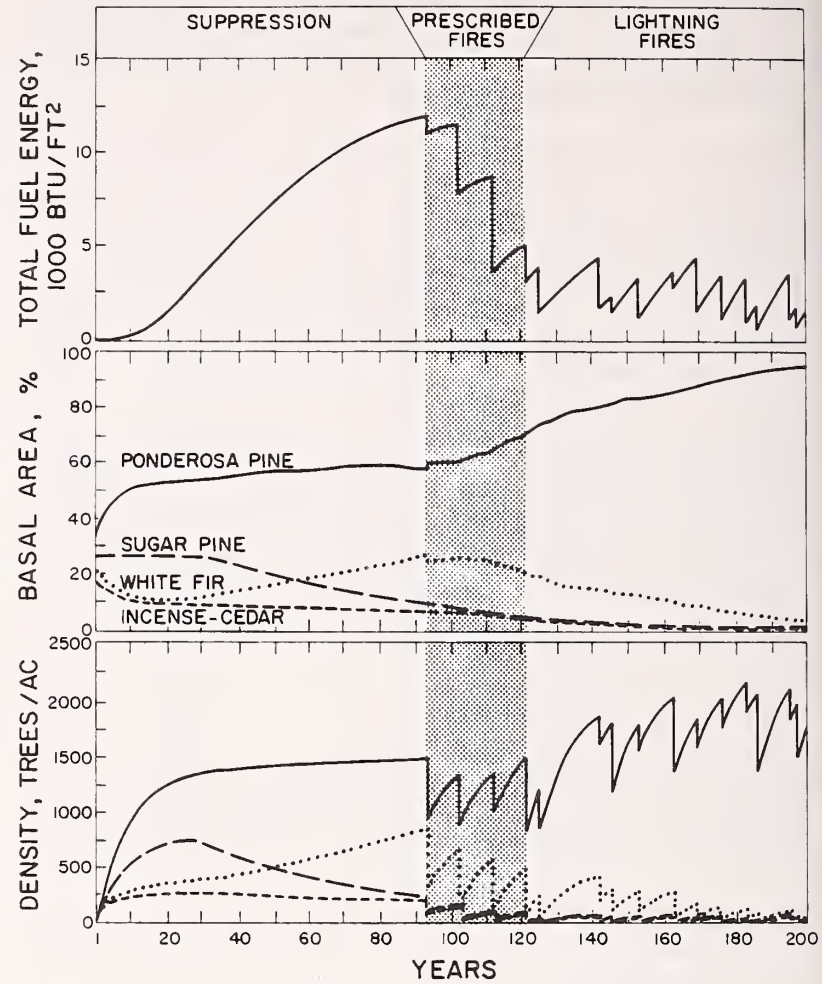

Figure 5.--Total fuel energy, percent basal area, and density effects under the prescribed fire scenario for a 200-year run of the FYRCYCL model.

DISCUSSION

The results of the simulation have ecological implications and can be applied to wilderness fire management. Future development of the model will enhance its use.

Ecological Implications

Without fire white fir would obviously replace ponderosa pine in wilderness ecosystems with short fire intervals because heavy shade and deep litter in these ecosystems give the firs a competitive advantage. Fire has always been a part of these ecosystems and will continue to be regardless of human efforts to intercede. Favorable weather conditions, sufficient fuel, and lightning ignitions simultaneously occur often enough to produce periodic fires that maintain an ecological state different from that which would occur without fires.

As seedlings, each of the species is susceptible to fire. Ponderosa pine soon gains an advantage by having a higher survival rate in open conditions and by growing faster. The pines also develop thicker bark at a younger age and have higher crowns. The interval between fires is long enough to allow the seedlings to become established and grow out of the reach of low-intensity fires. The 34 years before the first fire in the lightning-fire scenario shows the mechanism by which the stands become established. A longer interval would allow too much fuel to accumulate, leading to the possibility of a high-intensity fire.

The simulation showed that some fires burned in the spring and fall. These fires were not uniform, nor would they burn every spot with equal intensity. Because some areas did not burn, some trees of different sizes and species were still able to reproduce. A mosaic of groups of trees similar to the aggregations described by Bonnicksen and Stone (1982) will be perpetuated in these areas.

Over time, ecosystems reach a point of stability called a steady state. Fluctuations occur around a relatively stable average condition. Without fire, the steady state for mixed conifer ecosystems changes from ponderosa pine to white fir because it is able to reproduce in its own shade. Fire acts as a perpetuating mechanism in these ecosystems for ponderosa pine. The steady state is reached around the average condition as shown in the fuel and density graphs (fig. 2, 4).

Fire also prevents complete alteration of the ecosystem. When small accumulations of fuels burn, heat energy is lost. There is a cycle of energy loss and accretion corresponding to the interval between fires. Without periodic energy loss there would be an energy buildup of considerable proportions. The inevitable fire would reduce the fuels with such intensity that the ecosystem would be permanently changed. Low-intensity fires in these ecosystems increase stability by reducing the magnitude of the fluctuations.

The model is useful because it shows the conditions necessary to perpetuate short-fire-interval ecosystems. Its value lies not in its ability to predict future events, but rather in its ability to show the inherent behavioral characteristics of such ecosystems.

Management Applications

Wilderness managers are charged with preserving and protecting wilderness areas in their natural condition. It is commonly accepted to include meadows, streams, lakes, wildlife, plants, mountains, glaciers, rain, and many other components. Less well accepted as natural are fuels, lightning fires, and insect and disease infestations; yet it makes no more sense to exclude fire from the wilderness than it does to exclude snow or sunshine.

The manager needs to allow natural processes to run their course, and in those cases where process has been interrupted to reintroduce the process as naturally as possible. For short-fire-interval wilderness ecosystems that have been subjected to fire suppression activities, prescribed fire is the most natural means available. The question then becomes how best to reintroduce fire. In particular, it is important to know how frequently to burn, how intensely to burn, and when to stop burning.

The results from the fire cycle simulation can aid in answering these questions. The first step would be to collect vegetation, fuel, lightning, and weather data for the area in question. The simulator is then run several times to determine average values for the mean fire interval and the mean fuel energy level. Runs are then made with the prescribed fire option in effect using those average values along with the number of years fires have been suppressed, the burning direction, and the months when prescribed burns will be set.

The results will indicate the number of years and prescribed fires necessary to return to the natural fuel energy level, the months when conditions would be met for prescribed fires, and the number of times backing fires would have to be used instead of head fires. This information is then used to design a prescribed burning program for a wilderness area. It is also possible a burning program will not be necessary and that lightning fires can be allowed to burn without reducing fuels. In any event, the simulator is one source of information managers can use to help meet the challenge of maintaining wilderness ecosystems.

Future Direction

All computer simulation models are simplifications of real-world processes. The modeler is faced with the dilemma of balancing these simplifications with real-world complexity. The more simplifying assumptions made, the less the model reflects the real world. The FYRCYCL model can benefit from serveral modifications, however, to make it a better management tool.

Agee (1973) pointed out that precipitation and erosion hazard subroutines should be incorporated into the model, and this will be done in the next version. The Rothermel (1972) rate of spread equation will also be added to replace the algorithms presently in the model. Other additions will include fuel generators for the larger size classes and the ability to specify upper and lower limits to prescription parameters. Once those changes have been made, the model will provide information useful in managing short-fire-interval wilderness ecosystems and in understanding the role of fire in those ecosystems.

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THE "UNNATURAL FUEL BUILDUP" ISSUE //

James K. Brown

ABSTRACT: Fuel buildup is a natural process that can become unnatural when certain kinds and amounts of fuel extend uncommonly across landscape. Unnatural fuel buildups occur more readily in short-interval types than in long-interval types and may never occur in some long-interval types. A knowledge of fuel buildup is important in planning how to introduce fire successfully but not in determining the need for it.

The phrase "unnatural fuel buildup" is troublesome because it lacks a commonly understood and accepted definition. To clarify this concept, I will emphasize that fuel buildup is a natural process that can become unnatural when certain kinds and amounts of fuel extend uncommonly across the landscape. For example, if practically all of the seral ponderosa pine in the Selway-Bitterroot Wilderness contained a well-developed understory of Douglas-fir ladder fuel, the situation would probably be considered an unnatural buildup because of the uncommon extent of this fuel situation. Although large buildups of fuel are usually referred to as unnatural, light accumulations may also be unnatural. For example, frequent human-caused ignitions could lead to unnaturally light fuel accumulations.

Unnatural fuel buildup, therefore, is a matter of degree or circumstances. A practical concern of land managers is to know the critical level of fuel buildup. This requires knowing when fuels on an area are increasing to a level much higher than before organized fire suppression. Kinds and amounts of fuel vary considerably over the landscape. The fuel mosaic is composed of dead and live vegetation on the ground and of vegetation that is vertically continuous with it. Each forest ecosystem probably has a characteristic fuel mosaic. When this characteristic mosaic becomes extremely unbalanced toward certain fuel situations, it is unnatural.

In discussing the impact of fire suppression on fuel buildup, Habeck (this Proceedings) and van Wagtendonk (this Proceedings) draw opposite conclusions. Nevertheless, both, in my view, are correct. In the absence of fire in short-interval types, fuels accumulate, particularly fine fuels, because of shrub and conifer understory development. The extent of this buildup seems significant enough to me to be viewed as unnatural in some areas.

In long-interval types, Habeck (this Proceedings) pointed out that impacts of fire suppression on plant succession and fuel accumulation have been minimal. This is especially true in the cedar-hemlock forests studied by Habeck and in the wet forests of the Pacific Northwest where fire intervals can be several hundred years. Although the occurrence of unnatural fuel buildups in these forests types seems unlikely (because decay rather than fire recycles the dry matter), the mosaic of successional communities in these wet forest types may have been affected by the past years of fire suppression. Certainly vegetation composition and structure would be affected over several hundred years of fire suppression.

Habeck showed that downed woody fuel loadings vary considerably with stand age. My studies throughout the Northern Rocky Mountains have also shown this, and I think our findings suggest that heavy fuel accumulations are not necessarily unnatural.

A major difference between long- and short-interval types is that available fuels are produced more readily in short-interval types. Development of substantial fine fuels from herbaceous vegetation and abundant, porous litter coupled with drier environments are major reasons for the usually higher flammability in short-interval types. The drier environments associated with these types produce cured herbaceous vegetation over much of the summer. Live ladder fuels become readily available to burn because of the flammable surface fuels.

Fire intervals and environments differ considerably among long-interval types. For example, cedar-hemlock forests occur in warm, moist sites and typically have very long fire-free intervals. Decay of dead vegetation and recycling of nutrients progress more rapidly than in cooler, drier sites. In contrast, subalpine fir forests with lodgepole pine as a seral species occur in cool, dry sites. Fire intervals vary widely here but tend to be much shorter in the same regions where cedar-hemlock forests occur. Decay of dead vegetation proceeds slowly. Interpretations of unnatural fuel buildups could differ considerably among these long-interval forest types.

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Habeck suggests that the fire potential from unnatural fuel buildup and continuity of cover in short-interval types will increase the likelihood of stand replacement fires in adjacent long-interval types, resulting in loss of old-growth trees. The question raised by his suggestion is whether fuel buildups in short-interval types increase the likelihood of fire in long-interval types. For cedar-hemlock forests, I suspect that fuel buildup in adjacent short-interval types is not a significant threat. Cedar-hemlock stands tend to occur on lower, moist sites affording some protection from wind. Except for small stands vulnerable to fire sweeping in from adjacent fuels, they must still burn from their own fuels. Too, I suspect cedar-hemlock stands were often recycled by surface fire during extremely dry years when burnout of duff caused extensive root mortality. Fuel buildup in short-interval types does seem likely to increase stand replacement fire in subalpine fir and lodgepole pine forests. These forests tend to lie above short-interval types. Fires developing in lower short-interval types could easily continue upslope and become crown fires in the subalpine fir and lodgepole pine.

I would also like to comment on the often-stated assumption that fuels accumulate with time. The generality of the assumption is implicit to the unnatural fuels buildup issue. Like many generalities, it is true sometimes but often misapplied. Vegetative biomass does accumulate with time because photosynthesis produces organic matter on a regular basis. Not all biomass is fuel, however. Forest fuel is organic matter that could burn if ignited. Some biomass is simply unavailable as fuel. For example, much biomass is synthesized annually in living tree boles that will not burn in forest fires.

Biomass becomes available as fuel in an irregular manner. Biomass from branches and tree boles becomes fuel when added to the fuel complex on the ground. Dead branches and tree boles accumulate on the ground in response to natural causes of mortality and factors causing downfall. Causes of mortality such as fire, insects, disease, suppression or natural thinning, and wind and snow damage affect stands at erratic intervals. Thus, buildup of downed dead biomass occurs in an irregular manner and is not necessarily related to stand chronology. In fact, fuel loadings and flammability can decrease with time because downed dead organic material decays. Regeneration of conifers develops live ladder fuels that in time may grow out of the surface fire zone. This also forms a pattern of an increase in available fuel followed by a decrease.

An interesting aspect of fire is that it both decreases fuels by consuming them and increases fuels by killing living vegetation. In short-interval types, frequent fires under a no-suppression regime maintain fuels at minimal levels. In long-interval types, however, fires under a no-suppression regime may increase fuels and lead to higher levels of flammability for longer periods of time than under a suppression regime.

Finally, I offer the thought that in most ecosystems, it is unimportant to judge whether fuel buildups are natural or unnatural. In managing wildernesses, parks, and other natural areas, our attention should be focused on maintaining a natural balance of successional stages. Mosaics of successional stages offer a more fundamental and reliable basis for determining naturalness than do fuel buildups. Fuel buildups coincide with certain vegetation successional stages in some ecosystems but not in others. For example, development of Douglas-fir ladder fuels beneath ponderosa pine represents a fuel buildup that coincides with that successional stage. Vegetation and fuels would be judged alike as natural or unnatural. On the other hand, in aspen forests extensive areas of mature and overmature age classes could reasonably be viewed as unnatural. Fuels, however, are highly variable and nearly always should be viewed as natural. Knowledge of fuel buildups is important in planning how to involve fire but not in determining the need for it. In other words, knowledge of fuel is important in appraising fire behavior potentials and planning strategies for ignition but not in deciding whether fire is needed to maintain natural ecosystems. Of course, this is not true outside of these natural areas where fuel buildups can indicate a definite need for prescribed fire.

A policy of fire suppression should lengthen fire-free intervals in both short- and long-interval types. In short-interval types, occasional escaped fires tend to be more severe and may reduce or eliminate open stands of old dominant seral species. Also, suppression over long periods could lead to losses of certain seral species through plant succession.

In long-interval types, such as subalpine fir on cool, dry sites, concern about unnatural fuel buildups may be legitimate even if desirable species or community types are present. Here lack of periodic fire might permit an unnatural tieup of nutrients that could unnaturally affect plant community composition and structure. In cedar-hemlock forests on warm, moist sites, however, decay might be rapid enough to prevent unnatural fuel buildups.

Regardless of whether fuel buildups are natural, fuel accumulations having high fire intensity and fire severity potentials must be reckoned with in managing fire. To manage for a natural role of fire, planned ignitions, in my view, are necessary to deal with fuels and topography that have high potential for fire to escape established boundaries or to eliminate undesirable plant communities.

It is necessary for practitioners to develop criteria that permit sound decisions on when to introduce scheduled ignitions. In developing these criteria, unnatural fuel buildups should be of minor concern in establishing the need for fire to maintain natural conditions but of major concern in deciding how fire can be introduced successfully.

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WILDERNESS FIRE MANAGEMENT AND AIR QUALITY

Dennis V. Haddow

ABSTRACT: Prescribed fire helps to maintain wilderness in its natural state, but it may result in air quality impacts that are unacceptable. This paper examines existing and proposed air quality regulations and how they may affect the use of prescribed fire in wilderness. It also describes methods that minimize the impacts of prescribed fire on air quality and the impacts of air quality regulations on prescribed fire.

INTRODUCTION

Fire can play a significant role in perpetuating an enduring wilderness resource. The use of fire by wilderness land managers is rapidly gaining attention as a methodology to help meet the intent of the 1964 Wilderness Act; however, the short-term effects of fire on air quality may extend beyond the wilderness itself. Air quality in wilderness (and nonwilderness) is regulated by State and Federal air regulatory agencies that have no land management responsibilities. In general, land management agencies and air regulatory agencies have different legal directives and management goals. If the two groups do not coordinate their efforts, the use of fire in wilderness may be unnecessarily restricted, and wilderness areas and the public may ultimately pay the penalty.

AIR QUALITY STANDARDS AND REGULATIONS

As required by the Clean Air Act, the Environmental Protection Agency (EPA) has developed National Ambient Air Quality Standards (NAAQS) for six air pollutants: carbon monoxide (CO), nitrogen dioxide (NO^2), sulfur dioxide (SO_2), lead (Pb), ozone (O_3), and particulate matter (TSP). For some pollutants EPA has set two types of standards. The first, the primary standard, is designed to protect health; the other, the secondary standard, is designed to protect public welfare (soiling, camp damage, etc.). These standards must be met in the ambient air: that is, anywhere the public has access. If they wish, States may set ambient air quality standards that are more stringent than Federal standards. States may also set standards for other pollutants in addition to those set by EPA.

The Clean Air Act gives States the primary responsibility for designing and implementing regulations to assure that NAAQS are met. Section 118 of the Act requires all Federal agencies to comply with both substantive and procedural portions of all Federal, State, and local air quality regulations. If a State requires an air quality permit for prescribed burning and certain other conditions, Federal land managers must obtain such a permit and comply with all conditions. The Prevention of Significant Deterioration (PSD) sections (160-164) of the 1977 amendments to the Clean Air Act designated certain national parks and wilderness areas in existence on August 7, 1977, as "Class I areas." For those Class I areas, the PSD provisions assign the Federal land manager (FLM) the responsibility of protecting air quality-related values from adverse air pollution impacts. The FLM can recommend that construction permits for new stationary sources subject to PSD regulations be denied. The only air quality-related value (AQRV) specifically identified in the Act is visibility. AQRVs not identified in the Act include flora, fauna, soil, water, odor, and cultural or geologic features. The FLM is also responsible for determining how much of an air pollution impact would be considered "adverse."

PSD applies to a select list of new or modified stationary sources (power plants, smelters, and others) that emit or have the potential to emit 100 tons/yr or more of any air pollutant. PSD also applies to any new source with the potential to emit 250 tons/yr of any pollutant. PSD regulations do not apply to prescribed burning; therefore, the FLM can disallow air pollution impacts in wilderness from new stationary sources and at the same time allow air pollution impacts from wilderness fire.

Section 169A of the CAA set "as a national goal the prevention of any future and the remedying of any existing impairment of visibility in mandatory Class I Federal areas which impairment results from man made air pollution." EPA and the States are responsible for developing plans and regulations to assure that such a goal is met. States may regulate prescribed burning, both in and out of Class I areas, to meet visibility goals.

Paper presented at the Wilderness Fire Symposium, Missoula, Mont., November 15-18, 1983.

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The objective in managing visibility within wilderness is to provide the opportunity for a natural visual experience. The key words are "natural" and "experience." In this context, natural is defined as unimpacted by humans; therefore, the objective is not necessarily to provide an opportunity for visual enjoyment, which is a purely personal matter. If smoke from fire is a natural part of the wilderness, the wilderness manager should allow this visual opportunity. Whether seeing or smelling smoke is enjoyable is determined by the individual wilderness user. It must be realized, however, that viewing the scenery through "clean fresh air" has been considered an important wilderness attribute by many wilderness users (Haddow and Blankenship 1983). Given the somewhat subjective nature of this aspect of wilderness management, wilderness managers must have written definitions of their air quality goals. For example, the Forest Service should define wilderness visibility goals in the wilderness section of the Forest Service Manual.

PROPOSED STANDARDS

For the past 6 to 7 years, EPA has discussed revising the NAAQS for particulate matter in order to specifically address those small particulates that endanger human health. The present TSP standard addresses those particulates less than 50 microns in diameter; the revised standards will include both inhalable and respirable particulates, which are no larger than 10 microns and 2.5 microns respectively. The standard for inhalable particulates, presently referred to as PM-10, was proposed in the Federal Register on March 20, 1984. The standard for respirable particulates is probably 3 to 5 years away from the proposal stage.

Smoke particulates emitted from prescribed burning are generally less than 1 micron in diameter. Their small size tends to make them a relatively small component of TSP; however, the smaller size specified by the PM-10 and respirable particulate standards will dramatically increase the significance of prescribed burning emissions. For example, in Oregon prescribed burning emits approximately 19 percent of all TSP. It represents approximately 56 percent of all PM-10 emissions and an even greater percentage of respirable particulate emissions (Batson 1983). When EPA proposes a PM-10 standard, it is doubtful they will mention prescribed burning or any other air pollution source in their draft. EPA will propose a numerical PM-10 ambient air quality standard and then leave it to the States to develop regulations to meet the standard. One of the first actions taken by the States will be to develop emission inventories to determine which sources are major emitters of PM-10. It will probably be at that time that the significance of prescribed burning emissions first becomes known to EPA and most States.

The emission factor document that EPA and most States have used in developing TSP emission inventories is commonly known as AP-42. The listed emission factor for burning of forest residue given in pounds of particulate emitted per ton of material burned may underestimate the actual emission factors for prescribed burning by a factor of 2 to 5. When EPA and the States adopt more accurate emission factors, the significance of the impacts of prescribed burning will increase even more.

Conversations with the EPA staff who are drafting the Federal Register notice for proposed PM-10 standards indicate that these persons have little or no understanding of prescribed burning; yet the States may turn to these people when they are developing regulations to meet the PM-10 standards.

SMOKE MANAGEMENT

Smoke management for wilderness fire consists of a prediction and monitoring program. To be able to predict, on at least a daily basis, whether smoke accumulations will reach unacceptable levels, the wilderness manager first needs a definition of unacceptable smoke levels. Such a definition must be developed in cooperation with the State air regulatory agency. The wilderness manager needs to monitor smoke accumulation and to be able to take fire control action when the predictions for monitoring results show problems. For each fire management area a smoke management program should be developed to the extent that it represents Best Available Control Technology (BACT). BACT is the control level required of most air pollution sources and is developed using environmental, economic, and energy factors. Examples of BACT for prescribed burning include reducing the amount of material consumed, reducing the emission factor, and avoidance of smoke sensitive areas. The procedures for developing a smoke management program have been well documented in the EPA document "Smoke Management--A Workbook for Balancing Air Quality and Land Management Goals" (U.S. Environmental Protection Agency 1982)

TOOLS NEEDED

Even in areas where State air regulators can be convinced that natural smoke should not be unduly restricted, States will probably require information on pollutants emitted and their impacts. To meet such requirements the land manager needs a number of prediction and measurement tools. First, the land manager needs to be able to predict concentrations of TSP and PM-10 in and out of wilderness. In most cases, lands designated as wilderness lie in mountainous, complex terrain. Modeling of air pollutants in complex terrain is extremely difficult. In fact, no existing terrain models have been approved by EPA, although a number of complex terrain models being developed show promise (Fox, Blankenship, and Dietrich, this proceedings).

The wilderness manager must also be able to predict changes in visibility caused by individual fires. The wilderness manager then needs additional tools to predict the impact that the change in visibility has on wilderness users. The development of visibility tools is only just beginning.

Where possible, the wilderness manager needs tools to monitor impacts on TSP and PM-10 concentrations, visibility, and the impact of smoke on the wilderness user.

COORDINATION AND EDUCATION

Therefore, to minimize the impact of new air quality regulations it is important for wilderness managers to begin educating EPA and State air regulatory personnel on uses and control methods available for wilderness fire. This education is necessary <u>before</u> new regulations are proposed; otherwise, our agencies may end up as adversaries in rule development hearings. In general, air regulatory agencies are receptive to programs and control strategies they understand.

Because air quality regulations are developed on a State-by-State basis, coordination and education of these people by wilderness managers must also be done on a State-by-State basis. Where possible, State personnel should be taken into the field to observe the impacts of fire.

The importance of coordination between the wilderness manager and air quality regulator cannot be overemphasized. Coordination efforts should be initiated by the wilderness manager because of his or her potential to be regarded as a polluter.

In summary, wilderness fire is subject to Federal and State air quality standards and regulations; and new standards may affect the use of fire even more. The best way for the land manager to meet the potential changes is to develop tools to predict and monitor air quality impacts and to coordinate policy making with Federal and State air regulatory agencies.

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Section 4. Park and Wilderness Fire Management Planning

INTRODUCTORY REMARKS--PARK AND WILDERNESS FIRE MANAGEMENT PLANNING

Robert E. Sellers

To introduce the subject of park and wilderness fire management planning, I would like to reflect back to 1973. In May of that year, about 25 fire managers from the fire control ranks gathered together in the smokejumper dorm in Missoula and held an informal workshop. This small meeting of interested fire people from the United States and Canada was scheduled to discuss a controversial subject: park and wilderness fire management. This original meeting became known as "The Agendaless Nonmeeting," and we dared to discuss such ideas as "let burn" and "looseherd" in our efforts to seek positive and appropriate changes in our standard fire control programs. In February of 1974, another such workshop was held, which Gene Benedict tagged as "The Unstructured, International Agendaless Nonprogram with Stories." So by just looking at the length of the title, we realized that some progress had been made in one 8-month period. I am happy to report that most of the people that attended those meetings are here with us today.

We held one meeting in the spring to tell each other what we planned to do with fire in the wilderness and one in the winter to nurse our wounds or discuss accomplishments. A high point of the winter meeting was the awarding of the coveted "Flap of the Year" award. This was presented to the fire manager whose fire activity the previous season showed enough originality to completely monopolize national media headlines.

We grew from 25 people in 1973 to 41 attendees in 1974. These informal workshops became so popular among wilderness fire managers that they became structured meetings, and of course once they reached that stage, they were canceled due to travel and budget restrictions. Our February 1974 meeting was interrupted by a knock on the door of the jumper loft, and a friendly gentleman asked if he could attend our meeting. His name was Bud Moore. Bud was then Chief of Aviation and Fire Control, Region 1, so we really didn't know how far we could trust him. But after he related a few stories of some of the things he had done with fire that never made it into his District reports, we knew he was one of us.

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Basically, our theme was, "Where are we in wilderness fire management? Where should we be? How do we get there?" We know now where we should be, and we will continue to learn the best way to get there. The road over the 10 years since our agendaless nonmeeting has not been without its bumps and chuckholes.

Bob Mutch and Dave Aldrich will not forget the day that the Fitz Creek Fire spotted across the canyon, and they had to quickly change roles from fire monitors to five behavior officers in a suppression effort.

Les Gunzel will not forget the day that first big prescribed natural fire in Saguaro National Monument smoked in the city of Tucson.

Bob Wood will not forget the weeks of pyrotechnics and smoke of the Waterfall Canyon Fire in 1974, when he and his fellow rangers were described as firemongers by the citizens of Jackson Hole and the national media.

Dave Butts will not forget watching the program he initiated in 1974 for Rocky Mountain National Park disintegrate in the flames of the Ouzel Fire of 1978, which threatened to wipe out the border community of Allenspark, Colo.

Dave Jay and John Maupin will always remember the attention that they received from the Governor of Idaho and others during the Gallagher Peak Fire of 1979.

And Larry Keown will not forget how his stomach felt when the Independence Fire was threatening the Selway Lodge in 1979.

But we have survived and are continuing to gain knowledge at meetings such as this and to learn how to progress in fire management. I am sure we all have felt the frustrations and anxieties of pushing a program that we feel is correct for the land, yet it seems to progress so slowly. But when we look back to where we were at the agendaless nonmeeting of 1973, we have to admit that despite budget restrictions, Environmental Protection Agency requirements, and external political influences, we have continued to move forward and have made measurable progress. An example of this progress can be seen here today; a gathering of over 700 people, all interested in sound fire management. Today the concept of prescribed fire in parks and wildernesses is well understood, and we have a definite, out in the open, up front agenda.

The next session on park and wilderness fire planning will highlight some considerations that perhaps weren't even thought about 10 years ago. Again, this is an indication that real progress has been made not only in our planning efforts but, more importantly, <u>in the acceptance of those efforts by public users of park and wilderness areas</u>. This is the real bottom line.

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THE WILDERNESS FIRE MANAGEMENT PLAN

Tom Kovalicky

INTRODUCTION

It is a pleasure to participate in this Symposium. I would especially like to thank the people that put the agenda together and brought in such a good cross-section of speakers. In all such meetings, the speakers do little more than distribute ideas. You, the participants, pick up on these, separate the wheat from the chaff, and through one-on-one discussions at disreputable places and disgusting hours, meld these ideas together to solve "real-world" problems, and to formulate policies that will ultimately guide our direction. I see by the looks of some of you this morning you have been doing a good job at this session.

OBJECTIVE

My topic for the next few minutes will be fire planning in wilderness. In the Selway-Bitterroot Wilderness, we have one of the oldest approved plans in the Forest Service. More important than the plan is the experience base that comes from working with prescription fire. An inherent part of any plan is an evaluation to determine the degree of success in meeting objectives. All wilderness fire management plans have basically the same objective: To let fire more nearly play its natural role within the wilderness. In reviewing the Wilderness Act of 1964, it is easy to understand the basis of this objective.

HISTORY

As many of you may recall, both the U.S. Department of the Interior, National Park Service, and the U.S. Department of Agriculture, Forest Service, followed a strict fire suppression policy for years. In 1968, the National Park Service changed its policies and in 1976 the Forest Service followed suit, thus enabling fire to reassume its historical role in modifying ecosystems. These first efforts were naturally cautious because a nation that had grown up with Smokey the Bear was reluctant to dismiss the "Prevent Forest Fire" education they had received as children. Political battles raged while Ship Island and Mortar Creek burned, and technology may have advanced faster than our ability to communicate, as Senators and Governors were quick to tell us.

Time has passed, political rheteric has cooled, plan prescriptions are more defensible, and the public is better informed and more understanding. The fire planning process is well defined and prescription fires are meeting desired objectives. Proof of this is given by Dr. Bruce Kilgore (1982) in the paper he presented last fall at Jackson, Wyo. Bruce told us of 26 national parks that are practicing a natural fire program and of 15 Forest Service-approved fire management plans covering many national forests and about 9 million acres (3.6 million ha).

I would like to say briefly what the Moose Creek Fire Plan has accomplished in the Selway-Bitterroot Wilderness. I hope that most of you had an opportunity to participate in the poster presentation and pick up a copy of the paper, "Five-Year Review of Fire in the Moose Creek Ranger District, Selway-Bitterroot Wilderness." Jim Saveland and Richard Hildner (in this proceedings) have done an excellent job of gathering facts and presenting ideas on tracking prescription fires on a high fire-occurrence District.

It is interesting to note that in the past 5 years, 155 fires burned a total of 26,551 acres (10 745 ha). This averages 31 fires per year, for a total burn area of 5,310 acres (2 149 ha) annually. Using these figures, slightly less than 1 percent of the District is affected per year. Of the 155 fires, 48 have been prescribed fires, accounting for 20,764 burned acres (8 403 ha). Most of which were produced by the Independence Fire, which Larry Keown will discuss later today.

CURRENT PROBLEMS

Fire planning and education are not without problems. Plans are subject to human interpretation, political constraints, emotional reactions, weather, availability of suppression forces, and air quality, to name a few. I mention these factors not because I advocate returning to suppression, but because I want to point out the complexity needed in the plan and the need for well-thought-out prescriptions. Speaking from

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experience, the first question I ask or am asked is, Are we following the direction given in the plan? To make the plan work, the line officer and staff must have an understanding of fire behavior and the planned prescription for fire management.

Another area of concern is the tendency to associate wilderness fire with targets such as winter range improvement or brushfield eradication. We have an educational problem with some of our own people! The reason for natural fire is simple: to let fire more naturally play its role in the ecosystem. In many of our areas, the vegetative community was established and perpetuated by fire. Through suppression the ecosystem has changed, advancing closer to climax than historically would have been the case. Prescription fire planning and execution allows a return to natural conditions. Game range improvement is a spin-off benefit, not a major objective.

Another problem that I feel the Forest Service has not resolved in its planning process is the recognition of loss of improvements through large fire occurrence. Often, trail maintenance costs increase following a large fire. Hot fires burn out trail cribbing and cause heavier maintenance, more trees across the trail, dislodged stumps, rocks, and other debris. This results in costly maintenance or reconstruction projects. Presently these costs cannot be carried by the fire monitoring fund and are not recognized in the Forest budget allocations. We need to identify costs and plan to meet needs on those units experiencing losses.

OPPORTUNITIES

We have talked of current problems. There are also obvious advantages to fire management. As most of you know, fire weather seems to follow a cyclic pattern and in moderate fire years the cost savings of the program are tremendous. In the Nezperce Forest 1983 was such a year with the Moose Creek District having only 13 fires. Only two Class A fires required control action, resulting in considerable cost savings and the beneficial treatment of 650 acres with fire.

Written prescriptions--spell out conditions under which a fire may be allowed to burn. Most plans set up units of land within wilderness boundaries. Interior units have broader prescriptions, allowing natural fire behavior under most expected conditions. Exterior units are those on the edge of the wilderness and prescriptions pertinent to them generally are restrictive, assuring the agency of fire confinement within established boundaries. This works well, but establishes a defacto buffer inside the wilderness.

The Nezperce Forest sees some advantages in expanding the area covered by a fire management plan. At this time we are analyzing the Selway Face for inclusion in the plan. Terrain and vegetative types are similar to those within the Selway-Bitterroot Wilderness. The area is not in the timber base but rather is excellent winter range and a part of the Wild and Scenic Rivers System. We believe our studies will indicate a positive benefit for putting this area into a fire management plan. If so, we will be able to include more wilderness acres in the broader prescription of the interior planning unit and still assure that the appropriate suppression response may be taken within the planned area.

SCHEDULED IGNITIONS IN WILDERNESS

This paper would not be complete without some discussion on the use of planned ignitions[1] in fire management planning. The Wilderness Act clearly addresses the natural role of fire, and natural fire certainly fit the intent of the Act. The issue becomes, What about small wildernesses where we have adjacent areas with high values? Is fire to be excluded from these areas? What about the effect of 70 years of suppression on fuel buildup? The issues could go on and on.

As a manager of the wilderness resource, I have serious doubts that we are ready to use planned ignition as many propose. I want to be assured, that proponents of this policy understand the objectives of the Wilderness Act and the bounds of their own knowledge and expertise.

SUMMARY

In summary, we have proven ability in the fire planning area. It is important that each person involved in the planning process feel a sense of ownership for it. It is even more critical that once the plan is approved, it is implemented. In spite of difficulties in implementation, the planning process must be allowed to work on the ground.

Following the plan may be the easiest part of the prescribed fire program. Informing and involving people outside the agency is also crucial to program success. The Park Service in Yellowstone National Park used a printed handout to tell about one of their high visible fires. The program was explained so well that tourists left the area--not complaining of the smoke--but excited about the experience and feeling a sense of participation. Newspapers, political figures, Fish and Game Departments, to name a few, are all necessary contacts and, when informed, will support the program.

Lastly, I think we need to be more creative, responsible, and willing to look to the real needs of the individual piece of land we are managing. Certainly, we need standards and guidelines, but we also need to grasp emerging techniques, realistically apply them to the benefit of that acre of land, and move ahead with deliberate planning.

[1]Editors' note: please refer to the Foreword for comments on prescribed fire terminology.

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ELEMENTS OF WILDERNESS FIRE MANAGEMENT PLANNING

William C. Fischer

ABSTRACT: Wilderness fire management planning is separated into six essential elements: (1) describing fire and ecosystem interactions, (2) describing special resource and use considerations, (3) defining fire management objectives, (4) delineating fire management units and zones, (5) developing fire management prescriptions, and (6) devising a fire management plan. The plan should reflect management direction for the wilderness area and enables managers to effectively implement stated objectives.

INTRODUCTION

The purpose of wilderness fire management planning is to produce a guide for all fire management actions within the wilderness planning area, including response to wildfire and the conduct of prescribed fires.

Wilderness fire management planning can be separated into six essential elements: (1) describing fire and ecosystem interactions, (2) describing special resource and use considerations, (3) defining fire management objectives, (4) delineating fire management units and zones, (5) developing fire management prescriptions, and (6) devising a fire management plan.

The elements are listed in proper sequence for planning and each depends in part on information developed earlier in the planning sequence. Prescription evaluation and plan revision are not listed as planning elements because they occur after the initial plan has been developed and implemented. Public involvement is not listed as a separate planning element because it will occur as part of the environmental analysis process. Subsequent actions directed at public information and involvement are elements of the fire management plan.

Terminology used in the following discussion of wilderness fire management planning is consistent with that proposed by Fischer elsewhere in this proceedings.

Paper presented at the Wilderness Fire Symposium, Missoula, Mont., November 15-18, 1983.

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FIRE AND ECOSYSTEM INTERACTIONS

The first step in wilderness fire management planning is to describe how the physical and biological characteristics of planning area ecosystems have been and might be affected by fire, the absence of fire, and fire suppression actions. Interactions between fire and other ecosystem components can be identified by delineating and describing planning area ecosystems in relation to their fire situation. Consider this to be a three-step process: (1) classify, describe, and map area ecosystems; (2) describe the fire situation; and (3) identify and describe significant fire-related interactions. (In practice these three steps may not be so clear-cut.)

Ecosystem Classification

Classification involves grouping similar objects and separating dissimilar objects. Classification brings order to our thinking and communication by systematically naming the objects being classified and showing the relationships among them. The purpose of classification for land management is to organize, communicate, and collect information for decisionmaking.

Identification and delineation of wilderness ecosystems are important because such classification provides (1) a basis for inventorying current resources, (2) a means of transferring experience and knowledge about a studied area to a similar but unstudied area, (3) a framework for assessing local management opportunities and predicting the outcomes of treatments or actions, and (4) a means for communicating among managers, researchers, and the public.

As a general rule, vegetation (current and potential), soils, and landforms should be mapped to provide a basis for delineating planning area ecosystems.

The Fire Situation

The second step in defining interactions between fire and other ecosystem components is to describe the fire situation for the planning area. "Fire situation" is an arbitrary term used here to identify of fire's historic role, the current potential for fire, and the probable effect of present and future fire on planning area ecosystems.

Fire history.--A requirement of wilderness management is to preserve natural conditions. The wilderness fire management planner must therefore understand the role played by natural fire, if any, in establishing and perpetuating natural conditions. The planner must also determine the probable effect, if any, of past fire exclusion. To understand the role fire has played, planners must determine the fire history of the planning area.

Fire potential.--Fire potential is an ecosystem's capability for fire. The traditional concepts of fire risk, fire hazard, and fire danger are incorporated within the concept. The important determinants of fire potential are probable fire occurrence, the fire environment, and probable fire behavior. Fire environment refers to the conditions, influences, and modifying forces that control fire behavior. It is composed of three interacting influences: fuels, weather, and topography.

An adequate evaluation of fire potential allows the planner to answer the following kinds of questions about the planning area:

1. How many fires are likely to occur in a season and when?

2. What kind of fuels exist and where?

3. What kind of weather conditions are likely to occur at different times during the burning season?

4. How might various fuels burn under the range of likely weather conditions?

Fire Effects.--Wilderness fire management planners need to identify fire effects that pertain to planning area ecosystems. To be useful, fire effects must be related to ecosystem classification and fire severity. Emphasis should be on characterizing the general effects of fires of varying severity on plant and animal succession and watershed properties.

Summary Of Interactions

Summarizing fire and ecosystem interactions requires setting down the major elements of the fire situation for each identified ecosystem. Such a summary will aid in identifying important differences in fire history, fire potential, and fire effects. These differences can, in turn, be valuable aids for developing fire management objectives, delineating fire management units and zones, and prescribing appropriate fire management actions.

Questions that should be answered for each ecosystem identified based on its fire situation include:

1. What is the natural role of fire?

2. How has fire suppression affected physical and biological characteristics?

3. When, where, and what kind of fires are likely to occur?

4. Are fires likely to intrude from an adjoining area?

5. How will future fires of varying intensity affect physical and biological characteristics?

6. How will fire exclusion affect physical and biological characteristics?

7. What environmental impacts are associated with various fire suppression methods and fire management strategies?

SPECIAL RESOURCE AND USE CONSIDERATIONS

Most wildernesses have unique features and permitted uses that require special consideration when planning fire management. Such areas should be identified, described, and mapped. This is often done in a higher-level plan. Areas requiring special consideration include (1) ecological, archeological, geological, and other features of scientific, scenic, or historical value; (2) rare, endangered, and threatened plant sites and animal habitats; (3) administrative sites and improvements; (4) designated recreation sites; (5) grazing allotments; (6) oil, gas, and mineral leases and exploration sites; and (7) nonfederal land within and immediately adjacent to boundaries. Appropriate specialists should assist in identifying special areas and in appraising probable effects of fire, fire exclusion, and fire suppression.

The important question to be answered is: How might fire or the absence of fire affect ecological, archeological, geological, and other features of scientific, scenic, historical, or cultural value?

FIRE MANAGEMENT OBJECTIVES

Wilderness fire management objectives state the planned measurable results desired from a wilderness fire management program. The overall goal toward which wilderness fire management objectives should be aimed is the preservation and enhancement of the wilderness resource through a well-planned and well-executed fire protection and use program that is ecologically sound and cost-effective.

Fire management objectives for a specific wilderness planning area depend on the fire-ecosystem interactions, special resource and use considerations identified for the area, and the wilderness management objectives set forth in the wilderness management plan or other appropriate land management plan. Relevant agency-wide fire management policy and other lower level direction (for example, legislation, U.S. Department of Agriculture regulations, and Regional Forester

instructions) should be reflected in the wilderness management objectives. If for some reason they are not, they should be identified and used as a basis for defining specific wilderness fire management objectives.

Defining of specific fire management objectives is the critical element in wilderness fire management planning. When this has been done, the remaining planning effort is, devoted to developing criteria and devising methods that assure accomplishment of the fire management objectives.

Fire management objectives should be clearly stated and explicit. They should encourage fire use where such use is ecologically sound and beneficial to management objectives. Conversely, fire protection should be required where necessary to assure visitor safety, protect private property, and to avoid undesirable environmental impacts. The following is a list of management goals and associated objectives relevant to many wilderness areas.

Goals	Objectives
Allow fire to achieve its natural role.	1. Perpetuate naturally occurring plants and animals. 2. Perpetuate natural vegetative patterns. 3. Maintain "natural" fire regime.
Use fire to accomplish its desired resource management objectives.	1. Restore fire where exclusion has had adverse effects. 2. Create, maintain, or enhance habitat for threatened, endangered, or desired plants and animals. 3. Prevent or abate undesirable fuel situations.
Protect life, property, and resources from unwanted fire.	1. Protect visitors. 2. Protect scientific, scenic, or historical values. 3. Protect recreation, administrative, and other imposed sites. 4. Protect intermingled and adjacent nonwilderness lands.
Avoid unacceptable effects of fire and fire suppression.	1. Maintain acceptable air quality. 2. Use low-impact fire suppression techniques. 3. Prevent unauthorized human-caused ignitions. 4. Avoid prescribing fire of "unnatural" severity.

The list does not exhaust the range of possible wilderness fire management objectives, and some of the listed objectives may be inappropriate for a given wilderness area. Fire management objectives should flow from the land management plan for the wilderness and should, consequently, be developed by wilderness managers and resource and fire management specialists. Fire management objectives should include such specifics as what, where, when, and so on. If, for example, an objective is to maintain favorable habitat for a rare species, the objectives should identify the species, describe favorable habitat conditions, and tell how much habitat needs to be maintained.

FIRE MANAGEMENT UNITS AND ZONES

Fire management unit and fire management zone are often used as synonyms. They are not so used here. *A fire management unit is a distinct part of the fire management area that can be recognized and mapped from its external features.* A particular drainage within a fire management area is an example of a fire management unit. It is, in a sense, a mini-fire management area. *A fire management zone refers to all the land within a fire management area that has some common characteristic.* The shared characteristic can be physical, biological, or use-related, for example, all the land above 9,000 ft (2 743 m) or all land that comprises grizzly bear habitat.

Fire management units and zones are delineated to help the planner write fire management prescriptions and develop and implement fire management actions. They enable the planner to focus on a particular piece or type of land and make integrating fire-ecosystem interactions, special resource and use considerations, and fire management objectives manageable.

The nature of the fire management area and the associated fire management objectives should determine whether fire management units, fire management zones, or both units and zones are delineated. Fire management zones are often used to divide a small fire management area that has relatively uniform characteristics. Fire management zones are also appropriate when fire management objectives are few and result in relatively simple fire prescriptions. Fire management units are often appropriate for dividing large fire management areas of diverse characteristics and for areas of any size where fire management objectives vary and require complex prescriptions. Both fire management units and fire management zones may be required in certain situations. A likely case would be a large fire management area divided into many large fire management units, each of which has several fire management objectives and special resource and use considerations.

Stratification of a wilderness fire management area into fire management units (FMU) and fire management zones (FMZ) depends on area size; physiognomy; ecosystem diversity; the fire situation; presence of unique features, special uses, and improvements; land ownership patterns; and fire management objectives.

Fire Management Units

Fire management units should be relatively large homogeneous areas with boundaries that are natural

barriers to fire spread or that at least provide a reasonable chance for fire containment. Mountain wildernesses can usually be divided into fire management units that correspond to major drainage patterns. Planning areas that lack a pronounced topography can be divided into units based on past fire patterns, major changes in vegetation or fuel type, or other appropriate criteria. Based as they are on external features, fire management units can easily be located on aerial photos.

Wilderness fire management planning and implementation can be based on a fire management unit basis if management units are delineated early in the planning process. Planning can then proceed one unit at a time.

Fire Management Zones

A fire management zone consists of one or more parcels of land within the planning area; these parcels have common fire management objective(s) that can be satisfied by a common fire management prescription. Fire management zones are usually composed of similar ecosystems having similar fire situations. They may, however, also reflect common special features or use considerations.

Delineating fire management zones is a synthesizing process. The fire management planner must translate wilderness fire management objectives into planned management responses to fire on specific pieces of land within the planning area.

A first step in identifying fire management zones is to aggregate lands on an ecological basis. The next step is to scrutinize the fire situation in ecologically similar units. Probable fire behavior and associated fire effects are key considerations during this step. This evaluation may produce new groups based on even more specific classification. During the next stage the manager must determine which lands require a fire management strategy that depends on considerations other than physical and biological characteristics and the fire situation. Included in this category are areas of ecological, archeological, geological, and other features of scientific, scenic, or historical value. Other considerations included are grazing allotment, wildlife habitat, and private property. Special fire management zones can be created to reflect the special fire management needs of such lands.

The final outcome of this process will be a number of fire management zones, each requiring a unique fire management strategy to accomplish stated fire management objectives for the planning area. Each of these zones should be described and their boundaries mapped. Fire management objectives and the desired response to fire for each zone should be clearly stated.

The number of fire management zones described for a planning area depends on the number of different desired responses to fire and whether or not these responses are absolute or conditional. In other words, is the desired response required at all times under all burning conditions or does it vary by time of year, weather conditions, or other variables?

Fire management zones usually reflect four primary responses to fire: (1) fire suppression, (2) observation, (3) scheduled prescribed fire, and (4) conditional fire management. Almost every existing wilderness fire management plan, for example, has areas where any fire at any time is undesirable. Such areas can be described as being in automatic fire suppression zone or fire exclusion zones. Other areas where fire is considered undesirable but where damage potential varies with site or burning conditions might be designated as falling into delayed attack zones. Fires occurring in such areas may not always need immediate attack. Still other areas where fire is generally unwanted may be designated as modified attack zones in order to prohibit fire suppression techniques deemed unacceptable because of adverse environmental impact. A primary response to fire, total suppression in this example, results in the designation of three fire management zones. Another primary fire response is to allow all fires to burn as unscheduled prescribed fires regardless of time of year, burning conditions, or other variables. Areas for which such a strategy is appropriate can be designated as observation zones. Areas designated for treatment with scheduled prescribed fires might be included in a single scheduled prescribed fire zone.

In many wilderness fire management planning areas most lands will fall into one or more conditional fire management zones designed to allow a conditional response to fire, depending on time of year, elevation, burning conditions, and other variables. Such zones are labeled in a variety of ways depending on external features, vegetation, use considerations, and other factors that best indicate the basis for creating the fire management zone.

The designation of fire management zones and the assignment of lands to fire management zones is interrelated with the development of fire management prescriptions for the zones. This is another case where planning steps are not clear-cut. One distinction that can be made between these two tasks is that fire management zones are delineated by the kind of fire desired or expected; fire prescriptions are based on conditions likely to result in the desired or expected fire.

There is an important relationship between fire management zones and fire management units. A properly designated fire management unit imposes an area constraint to fires that may burn within the unit's boundaries.

Each fire management unit and zone should be delineated on a map of the fire management area. A brief written description of each unit and zone should include information about important fire-

ecosystem interactions, special resource and use considerations, and relevant fire management objectives.

FIRE MANAGEMENT PRESCRIPTIONS

A fire management prescription is a written direction for dealing with the threat, occurrence, and use of fire within a fire management area, unit, or zone to accomplish land management objectives. Note that the scope of a fire management prescription is broader than that of a fire prescription. A fire prescription is a written direction for the use of fire. Traditional fire prescriptions are usually limited in scope. They primarily deal with the conditions under which a fire will be ignited, ignition techniques, and other factors directly related to the conduct of a burn. A fire management prescription must include necessary direction for the detection, prevention, and suppression of fires as well as for the use of fire.

Fire management prescriptions are usually written for a fire management unit or zone. Sometimes a single prescription will apply to several units with similar characteristics and fire management objectives. A single fire management prescription could conceivably apply to an entire wilderness fire management area, but such a situation is rare. The fire management prescription represents the culmination of fire management planning. Fire and ecosystem interactions, special resource and use considerations, and fire management objectives become manifest in the fire management prescription for a fire management unit or zone. The fire management plan, the final planning element, is a direct result of the fire management prescription(s). The plan tells how fire management prescriptions will be implemented.

The fire management prescription establishes standards upon which fire management decisions may be based. Criteria should be established for all fire management activities necessary to accomplish fire management objectives for the area of land covered by the prescription.

Prescription Development

It is difficult to suggest a step-by-step method for developing fire management prescriptions. Prescriptions that satisfy a given management objective in one planning area may fail to satisfy the same objective in another. No methodology can substitute for an intimate knowledge of the planning area, clear and concise management objectives, and a journeyman's knowledge of fire suppression, fire behavior, and fire effects. The following approach requires all four of these capabilities.

Partitioning the planning area into fire management zones and units can be an important first step in prescription development because such zoning reduces the often varied landscape to a manageable number of ecological land units and special areas for which prescriptions must be written. Preliminary prescriptions can be developed for each fire management zone based on the fire response desired in each zone. After preliminary prescriptions have been developed, each can be evaluated on a fire management unit basis. The lands within a given management unit may fall into a number of fire management zones; within each unit, prescriptions for neighboring zones must be compatible. To illustrate this point, consider a special fire management zone with a prescription that requires total fire suppression and an adjoining downslope zone where the prescription calls for allowing certain fires to burn as unscheduled prescribed fires. Unless there is a natural barrier to fire along their common boundary, these prescriptions could be incompatible. Fire suppression might often be required to keep fire from entering the total suppression zone. This is not cost-effective fire management. As a general rule, prescriptions for adjoining zones should consider the natural fire spread tendency of a free-burning fire given the topography of the management unit. To deal with such situations, fire management zone designations must often be adjusted or preliminary zone prescriptions altered to reflect actual on-the-ground situations within a given fire management unit. It is unrealistic to expect all prescribed fires to remain in prescription unless the prescription is broad enough to allow a fire to encompass all the flammable area in its natural path. It is also unrealistic to depend on control action as a regular means of containing fires within a designated area. Minimal control or holding action along a well-defined natural barrier to fire spread is the only practical approach to using unscheduled prescribed fire for attaining wilderness management objectives.

Another reason to prescribe fire management on a unit-by-unit basis is that fire management activities such as detection, prevention, and presuppression are best prescribed for a homogeneous unit of land that is easily identifiable on the ground.

Suggested procedures for developing prescriptions for scheduled prescribed fires are generally available. Such prescriptions should contain directions for responding to unscheduled fire that might occur in areas where prescribed fires are scheduled.

Prescription Criteria

As indicated earlier, fire management zones are based on the planner's interpretation of acceptable and unacceptable fires with respect to management objectives. To develop fire management prescriptions, the planner must also consider the conditions under which these acceptable and unacceptable fires are likely to occur. A fire management zone may be described, for example, as a zone in which preseason and postseason surface fires of low severity will be allowed to burn. To write a

prescription for this zone, criteria must be established for preseason and postseason fires, for low severity fire, and for surface fire. These criteria must be measurable and immediately determinable at the time a fire is discovered. Examples of commonly used prescription criteria are elevation, calendar date, and fire danger rating indices.

Selecting prescription criteria requires knowledge of the relationship between prescription variables and fire behavior.

Prescription Constraints

Fire management prescriptions are not complete until all constraints are identified, defined, and incorporated into the prescription. Common constraints that often apply to wilderness fire management prescriptions have to do with human-caused fires (agency policy often prohibits their use as prescribed fires); scheduled prescribed fires (often prohibited in wildernesses); level of fire activity (prescribed fires are often shut down during periods of high fire activity); and crew availability (fire use is often tied to the availability of fire crews to handle possible escapes).

Prescription Content

For each management unit the fire management prescription should specify the response to fire or the threat of fire that is necessary to accomplish management objectives. Specifications should include fire detection, fire protection, pre-attack, fuel management, and planned use of fire. Specifications for the planned use of fire comprise the fire prescription. Prescriptions for each fire management zone are separate and include specifications for (1) conditions under which fires will be aggressively attacked and suppressed, (2) conditions under which fires will be suppressed but less aggressively, (3) constraints on suppression techniques, (4) conditions under which accidental fires will be allowed to burn as prescribed fires, and (5) scheduled, manager-ignited prescribed fires.

FIRE MANAGEMENT PLAN

Fire management prescriptions tell how to achieve fire management objectives for the planning area. The fire management plan tells who will do what and when and where the fire management objectives will be accomplished.

Decision Scheme

A major part of the fire management plan is a decision scheme for implementing the fire management prescriptions for the planning area. The decision scheme assures that all prescription criteria and constraints are systematically considered before a response to a fire is selected. It should allow the fire manager to quickly determine if a fire is a wildfire or an unscheduled fire as defined by the fire prescription. The scheme should also indicate, again according to the prescription, what attack and suppression methods are appropriate if wildfire is indicated. This same decision scheme, if properly constructed, is used to help determine if a prescribed fire continues to burn within prescription on a daily basis.

Assignment Of Responsibility

The plan should identify who is responsible for determining appropriate action regarding fire. Fire management prescriptions and associated decision schemes are guides for decisionmaking. Decisions regarding fire should rarely, if ever, be automatic. Current technology for predicting fire behavior and associated fire effects is imperfect, and the probability of unanticipated burning conditions is great. Decisions must be based on what a fire is actually doing and what it is likely to do, not on some prefire prediction of what it is supposed to do. Fire management decision systems should, consequently, always include diagnosis by experienced fire and resource specialists. The plan should require such diagnosis and specify the level of expertise required of such decisionmakers.

Fire Monitoring

The plan should include procedures for fire monitoring and qualifications of fire monitors unless established standards apply. Fire monitoring provides the information needed to make daily decisions regarding prescribed fires, information needed to cope with agency requirements for documenting fire management actions, and information that can be used to verify or adjust fire prescriptions.

Scheduled Prescribed Fires

A schedule of all manager-conducted prescribed fires planned for the wilderness is an important part of the plan. Burning plans for these fires should also be included. A separate decision scheme for identifying prescribed conditions for scheduled fires may be desirable.

Evaluating Fire Effects

The effect of a prescribed fire or a wildfire in terms of wilderness fire management objectives is the ultimate test of the fire management prescription. The plan should contain a fire effects evaluation procedure and a procedure to use results of such evaluations to make necessary adjustments of prescriptions.

Fire Prevention

Most wilderness fire management prescriptions require suppression of all unauthorized human-caused ignitions. Fire prevention activities should therefore be included in the plan.

Fire Presuppression

The manager should identify and describe presuppression activities relevant to the fire management prescription in the plan; such items include detection, preattack plans, preparedness requirements, mobilization of forces, dispatching procedures, and collection of data for fire danger rating. Only those items relevant to implementing the fire management program for the wilderness area should be included.

Fire Suppression

The plan should indicate fire suppression standards and constraints not included elsewhere and procedures for determining actions when fires escape.

Visitor Safety

The plan should specify all special actions necessary to assure visitor safety when fires are burning in the wilderness area.

Smoke Management

The plan should identify actions necessary to comply with rules, regulations, and other requirements for maintaining air quality.

Public Information And Involvement

The support of resource managers and the general public is necessary to develop wilderness fire management effectiveness. Wilderness fire management plans should therefore outline a program of public involvement and information regarding planned fire management activities in the wilderness. This program should include participation by the agency, as well as by cooperating Federal and State agencies.

Notification And Reporting

Requirements for notifying designated agency and cooperator agency officials and filing necessary in-service reports of wilderness fire management activities should be spelled out in the plan. Responsible individuals should be identified.

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ARCHEOLOGICAL CONSIDERATIONS FOR PARK AND WILDERNESS FIRE MANAGEMENT PLANNING

Bruce A. Anderson

ABSTRACT: Land managers are becoming increasingly aware that cultural resources are a fragile and nonrenewable part of the environment that must be protected. Legislation has been enacted at the Federal and State levels to protect these resources. There is potential for conflicts between the goals of fire management programs and cultural preservation programs because fire may damage the resources and suppression may do even greater damage. Archeological surveys and collaboration between archeologists and the fire management team can mitigate this damage.

INTRODUCTION

Only in recent years have many managers realized that cultural as well as natural resources are vulnerable to wildfires, not only to the fire itself but from suppression activities. Fire effects are obvious on historic structures such as standing buildings; however, effects on archeological remains can be subtle and not easily recognized. Most land-managing agencies have cultural resource specialists (archeologists, historians, or historic architects) on their staffs, and these professionals should be consulted during the fire management planning process. In this discussion, I present some suggestions that may facilitate such a collaborative effort.

POLICIES AND MANDATES

Archeological resources can include sites, artifacts, and other data that can be used to reconstruct the varying life ways of an area's past inhabitants. These resources are a limited, fragile, nonrenewable part of the environment; when disturbed, the scientific information they provide is often lost forever. Because of the fragile nature of archeological and historical resources, there has been an ever increasing concern for their protection and preservation. This concern is clearly set forth in a number of acts:

1. The Antiquities Act of 1906 (Public Law 59-209, 34 Stat. 225; 16 U.S.C. 431-433);

2. The Historic Sites Act of 1935 (Public Law 74-292, 49 Stat. 666; 16 U.S.C. 461-467);

3. The Reservoir Salvage Act of 1960 (Public Law 86-523, 74 Stat. 220; 16 U.S.C. 469-469c);

4. The Historic Preservation Act of 1966 (Public Law 89-665, 80 Stat. 915; 16 U.S.C. 470);

5. The National Environmental Policy Act of 1969 (Public Law 91-190, 31 Stat. 852; 42 U.S.C. 4321-4347);

6. The Archeological and Historic Preservation Act of 1974 (88 Stat. 174);

7. The American Indian Religious Freedom Act of 1978 (Public Law 95-341, 92 Stat. 469);

8. Archaeological Resources Protection Act of 1979 (Public Law 96-95, 93 Stat. 721; 16 U.S.C. 470);

9. The National Historic Preservation Act Amendments of 1980 (Public Law 96-515, 94 Stat. 2987).

Most States also have legislation affecting archeological resources. In some States, programs for the investigation, protection, and recovery of archeological resources have been established and are active. Most States have historic preservation officers who review the State's varying projects and programs to see that cultural resources are addressed. Also, these offices direct and conduct State-wide surveys of historic properties and maintain a listing of those properties.

Finally, most Federal agencies have their own policy statements regarding cultural resources management. The U.S. Department of the Interior, National Park Service, has assembled a guideline entitled "Cultural Resources Management: NPS-28," which directs managers how to best care for cultural resources. This detailed comprehensive guide presents step-by-step approaches for all aspects--archeological, historic, and preservation--of

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cultural resources management. It must be remembered, however, that the National Park Service is unique because it is directed to preserve many of the best of the Nation's cultural treasures and has a different mandate for resource use.

STATE OF KNOWLEDGE

The focus in this section is on cultural resources and fires within specific park and wilderness areas. For several years researchers have discussed the role of Indian fires and their influence (Holbrook 1944; Burgh 1960; Stewart 1956, 1963; Reynolds 1959; Lewis 1973; Dobyns 1981; Barrett and Arno 1982; Pyne 1983). Although this question is extremely important to developing a knowledge of fire history and in determining the role of fire and of human influences before European settlement, it does not consider the effects of fire on the cultural resources themselves. Studies on direct effects are somewhat limited; they should become more numerous now that prescribed burning has increased (Switzer 1974; Racine and Racine 1979; Eisler and others 1978; Kelly and Mayberry 1979; Scott 1979; Traylor and others 1979; Manuel 1980; Noxon and Marcus 1983; Welch and Gonzales 1982). A drawback to some of these reports is that much of the information is based on observation and speculation rather than on tested results. These reports, however, are the only literature on fire effects and thus, when used to formulate planning, can be important. Finally, an excellent and more extensive source of information is the numerous reports on archeological surveys and excavations throughout the United States. Generally, these can be obtained through State universities, museums, or from other archeological research institutions. Most Federal agencies maintain cultural resource references for the areas they are concerned with or have staff archeologists maintain work libraries for relevant areas. Although these reports probably will not specifically concern fire-related situations, they can be extremely useful for fire management planning.

PROBLEMS

We need to be aware of potential conflicts between fire programs and other interests, and care should be taken not to destroy important archeological or historic resources (Parsons 1977). During any fire the four basic sources of damage to cultural resources are fire intensity, duration of heat, heat penetration into the soil, and the use of heavy machinery for fire suppression. The most significant threat to archeological resources is from heavy equipment used during the suppression activity (Traylor and others 1979). In known cultural resource areas bulldozers and graders should be monitored and directed by archeologists during the construction of firelines, fire roads, fire camps, and heliports and during followup rehabilitation operations like clearcutting, contour grading, and reseeding.

The most important source of information is the archeological survey. The more we know about any area's resources, the better the management plans will be for that area. A complete ground survey and inventory with detailed maps of sites, features, and environmental data are the best sources of information. For areas where a 100 percent survey is not possible, sample surveys, literature searches, assessments, and overviews should be completed to provide a baseline of information for making informed decisions. Often, however, cultural resource investigations are given such low priorities that they do not receive adequate funding. Even though there are laws, rules, regulations, and guidelines (mentioned previously) that call for cultural resource inventories, without the funds and available staff to deal with these requirements, often nothing gets accomplished. I realize that no agency will ever have all the funds needed to accomplish all of its goals, but managers should reevaluate priorities given for basic resource information. To ensure that cultural resource information is provided, funding should be appropriated by those requiring the information.

Another problem is scheduling, sequencing, and phasing the cultural resources work to be accomplished for planning needs. Sufficient lead time must be given to the cultural resources managers to provide the necessary information for those preparing fire management plans. If there is proper sequencing, the cultural resource information available can be used in the planning process. Also, by multistage phasing of the research to be accomplished, the information base can be built upon (as funding does become available), and the information previously gathered will not have to be acquired again. Staging the research also allows for reevaluation of what is needed as the work is being done. All of these aspects should be part of any effective cultural resources management program.

I also see communication problems in many agencies. Too often managers do not communicate well amongst themselves on how to accomplish the necessary work. Occasionally, people become so caught up in their own goals, research, needs, and ideals that they lose track of other important issues. If a combined team approach can be used to achieve agreement about the task at hand, we will be much closer to accomplishing the desired results.

CASE STUDY

In June 1977, a wildfire in Bandelier National Monument burned over 15,000 acres (6 070 ha) before the fire was contained. Because of the extensive cutural resources in the Monument, archeologists from the Southwest Cultural Resources Center, Santa Fe, N. Mex., were sent to work with the fire crews. The National Park Service Division of Natural Resources realized the suppression

activities were potentially dangerous to the archeological resources and suggested including archeologists in the fire-fighting scheme. This was the first such collaboration, and initially the fire bosses were apprehensive about archeologists working directly on the firelines. Later, however, they appreciated the efficiency of the arrangement in order to simultaneously suppress the fire and protect the cultural resources. Archeologists were most useful during fireline construction, when they guided crews away from sites, but they were also useful in other ways. By working day and night with the line crews, they were able to guide overhead teams (not familiar with the rugged terrain) to rendzvous points with other crews, to provide detailed maps of the area, and even to give interpretive talks to the line crews during lulls in the suppression activities. When the fire was finally contained, they also worked with the mopup crews.

Following the fire, researchers (Traylor and others 1979) studied the effects of the fire and the suppression activities on the cultural resources in Bandelier National Monument. This research was designed to:

1. Survey all areas affected by fire suppression within the Monument boundaries.

2. Survey two wildlife transects established before the fire and to complete the resource data for those areas.

3. Excavate selected sites burned by the La Mesa Fire to obtain data on the specific effects of the fire on artifacts and the sites themselves.

4. Submit a report on the findings with recommendations for actions in future fires where cultural resources are endangered.

Because a complete site inventory was lacking for Bandelier, the survey added to the data base. Of the 99 archeological sites surveyed, about two-thirds (58) had been burned in varying degrees. Some sites were burned heavily because of dense surface vegetation; others served as natural firebreaks due to an absence of vegetation (Traylor and others 1979; Fiedler 1979). Surface artifacts and stone (used for original site construction) were affected by the fire, and materials were slightly displaced. The major destruction to cultural resources, however, was caused by heavy machines. Only two sites were damaged during the initial construction of the cat lines, but later widening and rehabilitation of those lines (when archeologists were not present) caused six additional sites to be destroyed and seven others to be significantly damaged. During mopup minimal damage occurred on three sites where burning roots were dug out of rubble mounds. When the survey was completed, four excavation sites were selected to determine subsurface damages to artifactual and ecofactual materials. Samples were taken from controlled levels and sent to consultants. These included tree rings, pollen, flotation, soil, faunal, archeomagnetic, carbon 14, obsidian, and thermoluminescent materials. Damage ranged from very light to severe. Some effects, such as soil erosion, may not be known for years to come. Results of specific tests on the materials mentioned helped reveal the effects the fire had on both the surface and surface materials. Measurements of thermoluminescent values for pottery revealed dates 24 percent lower than expected for LA 16,097 (the most severely burned excavated site, as compared with only 10 percent lower at LA 16,114 [a moderately burned site]). Obsidian was also greatly affected, as only 35 percent of the examined burned sample edges revealed measurable hydration rinds, whereas 70 percent could be measured from unburned samples. Pollen is destroyed at 570° F (300° C), so surface pollen was definitely affected; however, subsurface pollen grains were protected.

Although this study did not benefit from previous survey information or comparative prefire data, two points were made clear: (1) archeologists working in cooperation with firefighters can prevent needless site destruction and (2) a fire as intense as the La Mesa Fire has a definite adverse effect on surface artifacts and architectural features.

Recommendations based on this study include:

1. It is essential to keep communication lines open at all times and to all factions involved.

2. Contingency plans should be established by area resource managers indicating resource priorities and permissible policy.

3. Resource base maps showing archeological site locations should be given to archeologists and fire bosses on the firelines.

4. When numerous cultural resources are threatened by a fire, archeologists can and should be present to help mitigate fire suppression or rehabilitation impacts on those resources.

5. Priority should be given to monitoring heavy equipment through all aspects of the suppression efforts.

6. All archeologists serving on the fire should have completed certified courses on fire behavior and hold a current red card.

7. Line archeologists should be equipped with appropriate standard safety equipment.

8. Special flagging should identify archeological sites.

9. A photographic record should be kept of all fire suppression and archeological activity.

10. A liaison officer should coordinate all activities of line archeologists with fire bosses.

We cannot forget that during a wildfire the highest priorities are safety and controling the blaze; therefore, if the fireline cannot be diverted, cultural resources may have to be sacrificed. In most cases, however, damage can be averted.

CONCLUSION

This paper has provided some considerations regarding cultural resources that should be made in park and wilderness fire planning. Some of the items discussed are most useful for planning, some are best for prescribed burning itself, others involve prevention and actual fire fighting and suppression activities. The time is appropriate for fire managers and cultural resource managers to begin working together. Through a combined concentrated effort, cultural resources can be saved for the enjoyment of future generations. These fragile, nonrenewable, finite resources are too valuable to be lost forever.

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VISITOR PROTECTION IN PARKS AND WILDERNESSES:

PREVENTING FIRE-RELATED ACCIDENTS AND DISASTERS

Robert W. Mutch and Kathleen M. Davis

ABSTRACT: As visitations increase in areas where fires are allowed to burn for days, weeks, or even months, the likelihood of human contact with prescribed fires in parks and wildernesses also increases. A recent survey indicated no direct threats to public safety have occurred to date from prescribed fires started by lightning, but if an injury or fatality should occur, difficult questions will be raised regarding the adequacy of precautions taken to prevent accidents or disasters. To help managers safeguard visitors the terms accident and disaster are defined, and the six stages associated with a prescribed fire disaster are listed. Also, adjustments are described to ensure the safety of visitors through the prevention of accidents and disasters.

INTRODUCTION

Seven million acres (2.8 million ha) of national parks and 9 million acres (3.6 million ha) of national forest wildernesses in the United States have been designated as areas where lightning-caused fires are allowed to burn (Kilgore 1982). More than 1,200 lightning-caused prescribed fires have burned about 190,000 acres (76 900 ha) of national parks and national forests in order to meet the management objective of perpetuating natural ecosystems. In addition, more than 840 human-ignited prescribed[1] fires were ignited in 26 national parks, burning some 180,000 acres (≅73 000 ha). The size of the prescribed fire program is large and still growing, and these areas are being visited by an increasing number of people each year.

The results of a recent survey, to be reported in depth later, indicated no direct threats to public safety have occurred as yet from prescribed fires started by lightning. If an injury or fatality does ever occur, however, people will undoubtedly be more understanding if it results from a wildfire that was being suppressed from its inception than if it results from a prescribed fire that has been allowed to burn for weeks or months. In the latter instance, difficult questions will be raised regarding the adequacy of precautions taken to prevent an accident or disaster.

Recent examples of prescribed fire from planned ignitions are not comforting. The 1979 Geraldton Fire (McCormack and others 1979) in Ontario, Canada, killed seven members of an ignition crew 7 minutes after ignition! The 1980 Mack Lake Fire, a wildlife habitat burn in Michigan, killed one employee, destroyed over 40 structures, burned over 20,000 acres (≅8 100 ha), and threatened a resort community. The plans for these fires had been written to carefully control ignition patterns to achieve management objectives and prevent escapes. Since these fires occurred, agencies in Canada and the United States have revised prescribed fire policies to improve the effectiveness and safety of operations, but even with new policies, are we doing all that is necessary to safeguard visitors in a growing program of prescribed fire using unplanned ignitions in the backcountry?

Basic to a discussion concerning visitor safety is the need to thoroughly understand the difference between the terms accident and disaster, because the precise difference is insidious but significant. An accident is defined as an unwanted event caused by an individual who does not adequately use established safeguards to cope with a hazardous situation. In other words, an accident is simply a result of an individual's failure to follow existing precautions. In contrast, Turner (1976), a sociologist who specializes in research on human adjustments to threats by the environment, defined a disaster as an event, concentrated in time and space, that threatens people with major unwanted consequences as a result of the collapse of precautions that previously had been culturally accepted as adequate.

Understanding the developmental sequence of Turner's six stages of a natural disaster helps prepare prescribed fire and wilderness managers to be more alert to changes in the prescribed fire environment in an effort to prevent disasters, while continuing to practice the fundamentals of accident prevention.

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[1]Editor's Note: Please refer to the Foreword for comments on prescribed fire terminology.

SURVEY RESULTS AND INTERPRETATION

A response form was sent to 60 land managers to survey the issues, concerns, and program safety procedures experienced in prescribed fire programs in parks and wildernesses in North America. Forty-six completed forms were returned. Five response forms were received from Parks Canada, 14 from the U.S. Department of Agriculture, Forest Service, and 27 from the U.S. Department of the Interior, National Park Service. No questionnaires were sent to the U.S. Department of the Interior, Bureau of Land Management offices because that agency then had no designated wildernesses.

The responses reflected experience gained from long-term programs, including Sequoia and Kings Canyon National Parks, Yosemite National Park, Selway-Bitterroot Wilderness, and Gila Wilderness. Responses also were received from areas that have programs but have had no fires or only a few small fires to date.

Most areas had programs less than 7 years old, and managers discussed experiences gained from developing programs. The diversity of responses was demonstrated by replies from managers of the chaparral-covered slopes of the Santa Monica Mountains National Recreation Area, which is bordered by Los Angeles basin development, to managers of Nahanni National Park, a 1,870-mi^2 ($\cong$4 840-km^2) wilderness park in the isolated MacKenzie Mountains, Northwest Territories, Canada.

Prescribed fire policies also vary. Some areas, particularly National Park Service lands in the United States, have prescribed fire programs using both planned and unplanned ignitions. The Forest Service, however, allows only unplanned ignitions in wilderness. For Parks Canada, the respondents indicated the same program variety. Some areas use prescribed fires from planned ignitions; others use unplanned ignitions to achieve resource management objectives.

Most of the questions we asked were about issues, concerns, and procedures regarding visitor safety. Visitors were the focal point because they are naturally less informed about fire than the land managers who develop fire programs. In addition, because most visitors are urban dwellers, they generally have less experience with fire and may not know precautions to take when near fire. Land managers are responsible for safeguarding visitors during prescribed fire and wildfire operations.

An analysis of survey results and a review of world-wide safety precautions (Davis and Mutch 1983) disclosed that some land managers are not fully aware of safety procedures, especially when people become entrapped by fire. Many respondents, however, stated the importance of adequately informing prescribed fire personnel about safety procedures. They also emphasized the need for <u>qualified</u>, <u>experienced</u>, and <u>patient</u> people to implement prescribed fire programs. One respondent cautioned us to treat all fire as fire and not to be lulled into thinking that prescribed fires are always under control. Consequently the survey results are applicable to land managers as well as to visitors.

The survey questions and responses are presented below. Common and widespread safety practices are summarized for each question, sometimes followed by unique or particularly useful actions.

1. In What Ways Have Visitors Been Threatened, or Potentially Threatened, by Prescribed Fires?

Only a fourth of the respondents listed threats. The most common were intense fires, erratic fire behavior, being blinded by or breathing smoke, falling snags, rolling burning material, and a fire burning out of a prescribed fire zone. Visitors who want to watch or photograph the fire may move into unsafe situations. One respondent reported problems with children sneaking past the ranger to get a closer view of fire. One young visitor received slight injuries when he stepped into a burned-out stump hole the day after a burn. The area was signed.

Problems caused by perceived threats of fires escaping onto adjacent land can be alleviated by involving the landowners in planning, giving current information about fires, and giving tours of burns. One manager suggested closing an area for 5 years after a fire to keep people away from falling snags, stump holes, and other hazards.

2. What Concerns Have Visitors Expressed Regarding Their Own Safety in the Vicinity of Fires?

Respondents listed only a few personal safety concerns actually expressed by visitors. These included visitors asking whether they needed to change their itineraries, whether the fire would interrupt their planned trip, whether it was safe to travel in the area, and whether smoke is a health problem. In one case, outfitters were concerned about traveling on trails in the fire area.

Visitors often expressed a general curiosity about fire and smoke and wanted to take pictures. Local surveys in several national parks show most visitors contacted understand why prescribed fire is used and support fire programs. Those respondents, however, were not immediately threatened. The importance of educating and informing the public cannot be overstated, because land managers still have visitors extinguishing or reporting fires when they are unaware they are prescribed.

By having a low-profile program with fires in remote areas and none in developed zones, managers can reduce visitor concern. Such practices may avoid the question, however, and limit opportunity for education. The strongest responses to this proposal came from managers indicating that visitors are generally unaware of possible

dangers. There is clearly a need to teach correct human behavior in fire situations regarding evacuation, escape routes, avoidance, and refuges so that expanding prescribed fire programs can maintain a positive safety record.

3. What Measures are Being Taken to Ensure Visitor Safety from Wildfires in More Developed Zones?

Common responses included total suppression, fuel reduction activities, evacuation, closures, public education, interpretation, regular fire patrols, and individual contact. Landscaping and removing debris around buildings reduce immediate hazards.

Other procedures mentioned included:

o Providing current information to the public about prescribed fires and wildfires in the area.

o Developing a perimeter plan that includes escape routes, fuel reduction, safety refuges, and so on.

o Moving developments out of hazardous locations such as box canyons.

o Training staff in safety awareness and giving structural fire training.

4. What Suppression Actions Have Been Taken to Restrict the Spread of Fires Toward Visitors?

Respondents mentioned usual fire control activities such as total or partial suppression, fuel reduction, patrols, retardant dropping, and burnout operations. Presuppression planning and suppression strategies should be designed to protect visitors from wildfires. Keeping visitors away from prescribed fires may not always work; thus, contacts in the vicinity of fires and information centers can help ensure an additional margin of safety.

5. Can You Provide any Examples from Public Involvement Sessions Where Visitor Safety Related to Prescribed Fires Surfaced as an Issue or Concern?

People expect agencies to provide for safety. Most answered no to this question, and one respondent said there was a surprising lack of interest from the public on this topic. Another said safety has not been mentioned by visitors at interpretive sessions held during prescribed burns. Smoke was always the main complaint. The responses to this question showed more concern for notification, current information, and protection than actual physical safety. No respondent reported the public requesting information about what to do if threatened or trapped. Smoke rather than fire was the health concern. This probably indicates more people have encountered smoke, whether in wilderness or towns, and recognize that as a potential hazard rather than fire.

Common concerns stated were notifying landowners, homeowners, and visitors about fires, having adequate control to keep the fire in prescription and off other lands, and the question of smoke as a hazard to health, traffic, or air quality. Outfitters expressed concern for camps, campsites, and hunting grounds. Other specific concerns were protection for property, mining claims, transmission lines, and recreation improvements.

One respondent replied public involvement has supported prescribed fire programs in the national park. A typical response is that fires must be expected and that trip disruptions or cancellations are facts of life in a wilderness setting.

6. What Safety Problems, or Potential Problems, Have Occurred With in-Service Personnel on Prescribed Fires in National Parks or Wildernesses?

Many respondents answered this question by giving examples of carelessness and improper procedures. Injuries result because workers do not watch their footing, look for obvious hazards (snags, stump holes), keep aware of surrounding activities, or wear protective gear. People tend to have a lax attitude and relax safety precautions around prescribed fire because it is a "controlled" burn. They sometimes do not use the same care they would to avoid the dangers associated with wildfires. Several replies stressed the importance of thorough briefings that identify potential hazards, safety precautions, operations, and objectives.

Having qualified, experienced personnel in charge of a burn and on the fireline is crucial. Respondents cited safety problems from poor leadership, inadequate briefings, inattentive holding crews, too many people, unclear chain of command, inferior radio communication system, and unclear instructions and burn objectives.

Problems can occur when there is insufficient control of the firing personnel. If they are not synchronized and coordinated, people can get entrapped. Are there too many burners or too few? Are they applying too much fire or too little? Patience is essential for burning safety and achieving resource management objectives.

Weather strongly influences fire, and its changeable nature affects safety concerns. Problems arise when weather predications are inadequate and ignitions occur at peak of the burning period. The use of test fires during planned ignitions can help determine the effects of prescribed fire behavior on achieving resource management, control, and safety objectives.

7. How is Fire Monitoring Used to Collect Information That Might Better Safeguard the Welfare of Visitors?

Data collected are used to determine suppression actions, refine prescribed fire skills, and inform people. Suppression is based on threat to people

and property or on fire exceeding prescription. Monitoring provides data on behavior, fuels, spread, weather influence, and other factors; evaluation of these data permits managers to judge whether to contain a fire, close an area, evacuate people, or allow the fire to burn.

Observing and documenting behavior and postfire effects improve future operations when the information is used to refine prescriptions and burning procedures. More accurate predictions of behavior, local weather variability, and fuels augment safety precautions and suppression readiness.

Information gathered provides an update on fire behavior, movement, and safety hazards for visitors and in-Service personnel. Information dissemination through signing, personal contact, dispatch, or other means helps people avoid or move from unsafe areas. Closures are also based on current information.

Researchers monitor fires in various fuel and plant communities to improve predictions of expected behavior, short- and long-term spread, and effects. Although these data help managers plan and conduct fires, they are also useful for evaluating fire management programs. Fire history studies give an added dimension by reviewing the historical role and influence of fire and comparing that to changes resulting from decades of suppression. Such results also can help managers prepare better contingency plans for safeguarding visitors in highly flammable vegetation types.

8. In What Ways Has Smoke from Prescribed Fires Caused Direct or Indirect Threats to Human Health and Safety?

Most respondents reported no direct threats. Some, however, cited examples of health and visibility problems. Particulate matter causes respiratory ailments as well as eye and throat irritation, especially where smoke accumulates in low-lying residential areas or campgrounds. Smoke can impair visibility on roadways, aircraft runways, and water courses, thereby creating safety hazards. In canyons or lowlands smoke accumulation can confuse and aggravate users such as campers, hikers, and outfitters. Smoke could hinder evacuation in such areas.

Air quality bureaus administer visibility and air quality standards. Smoke from prescribed fires is one type of pollutant that concerns regulatory agencies. Managers must carefully consider burning factors that produce less smoke, such as time of day, season, fuel arrangement, fuel moisture content, fuel loading, historical fire occurrence, and ignition pattern. Obviously the manager has more control over smoke produced by planned ignitions than unplanned ignitions to reduce smoke production.

9. What is the Human Safety Problem Related to Prescribed Fires That Concerns You the Most in Parks and Wildernesses?

Answers to this question fell into two categories: management of the fire program and people awareness. Poor management of a program increases safety problems because it produces unqualified and inexperienced personnel, no plan, no briefings, impatient burners who like hot, fast fires, and poor communication. One respondent expressed concern about policies in some parks that separate prescribed fire and suppression functions between divisions. This practice means that personnel do not get experience on both types of fire. Other concerns were nearby fires influencing each other and creating extreme behavior or fires getting out of control. Managers need to be aware of behavior and possible dangers associated with various fuels and evacuation difficulties.

Entrapment is a concern when managers do not know the location of people near fire. A wilderness permit system and closures help keep track of people, but day users are often not required to get permits and some visitors do not comply. Clear communications through briefings, written instructions, and radio messages help fire personnel avoid entrapment on wildfires and prescribed burns.

Uninformed people are a problem. Respondents reported spectators who ignore warnings or are unaware of potential dangers and thus wander through burning areas. Some try to suppress fires, not knowing they are prescribed.

A repeated concern was for people (visitors or fire personnel) who do not know and practice safety precautions. People may panic when actually not endangered or be complacent when they should seek a refuge. Managers stressed the need to educate people about correct behavior in fire situations.

ANATOMY OF A DISASTER

Warning words glow green on a computer terminal in the fire dispatcher's office. This fire weather message is rolling across the terminal's screen on a mid-August day, 1985:

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RED FLAG WARNING

High pressure continues to build just east of the Continental Divide and is producing a strong east wind for west-side forests. Expect winds easterly 15-25 mph today with some gusts to near 50 mph possible during mid- and late afternoon. These strong winds coupled with afternoon temperatures of 95° to 100° and humidities below 15 percent will produce extreme fire danger this afternoon.

The outlook through Saturday: Continued hot and dry with gusty east winds again Friday. Chance of dry lightning by Saturday.

End...DWG

- -

Couple this weather forecast with two dozen lightning fires burning under prescription in the backcountry and numerous backpackers and horse parties scattered through a 1-million-acre (≅405 000-ha) wilderness at unknown locations and we have the ingredients for a potential disaster. A doomsday prophecy? Perhaps. A situation that will never happen? It hasn't so far. A probable combination of events? Yes.

The fire behavior consequences of such a weather forecast on multiple fire starts that have been accumulating during a deepening drought are obvious. Two-dimensional surface fires would become three-dimensional crown fires, rates of spread would increase dramatically, fire storms could produce long-distance spotting as multiple fires reinforced each other, and increased smoke production would drastically reduce visibility. Routine safety precautions call for trail signing, trail closures, distribution of safety brochures, and visitor contacts on the ground and from helicopters. But how effective are these procedures in coping with the scenario? The recreationists are in place, their exact locations are uncertain, and poor visibility makes ground and air contact impractical, if not impossible. Inability to cope effectively with this scenario would have a profound effect nationally on backcountry prescribed fire programs.

A series of questions beg an answer. Is the scenario realistic? What about a full-fledged disaster? Have we prepared adequately to safeguard visitors in a suddenly developing mass fire where routine actions may no longer be sufficient? Have we written appropriate contingency plans to protect visitors from disaster conditions? Or are safety and contingency plans prepared to prevent only routine accidents from falling snags, rolling rocks, and so on?

If injurious situations are to be prevented successfully during prescribed fire activities, the precursors leading to a prescribed fire disaster should be differentiated from those leading to an accident. As defined earlier, an accident results from an individual's failure to conform to existing precautions. Procedures are well established to help people prevent accidents. But the debilitating consequences of a disaster occur when precautions break down that previously had been accepted as adequate. Thus, serious and damaging results can occur unexpectedly due to the element of surprise. Adapting Turner's (1976) sequential model for the origin of disasters to the prescribed fire situation should better prepare managers to examine the effectiveness of current prescribed fire precautions. The sequence of events associated with the development of a prescribed fire disaster (Turner's model) is as follows:

Stage I Predisaster starting point:

a. Initial culturally accepted beliefs about prescribed fire hazards.

b. Associated precautionary rules set out in laws, guidelines for practices, and policies, and so on.

Stage II Incubation period: The accumulation of an unnoticed set of events that are at odds with the accepted beliefs about prescribed fire hazards and the precautions taken to avoid these hazards.

Stage III Precipitating undesirable event: Undesirable prescribed fire situation that forces a redirection of attention and transforms general perceptions of Stage II.

Stage IV Onset: The immediate consequences of the collapse of cultural precautions regarding prescribed fire become apparent.

Stage V Suppression, rescue, and salvage: The immediate postcollapse situation is recognized and fire control, rescue, and salvage activities are started.

Stage VI Full cultural readjustment: An investigation is carried out and beliefs and precautionary norms regarding prescribed fire are adjusted to fit the newly gained understanding of the character of prescribed fire hazards.

Stage I--Predisaster Starting Point

The disaster sequence commences with a set of culturally held beliefs about prescribed fire hazards. These beliefs constitute the "normal" stock of knowledge that is thought to enable individuals and groups to survive successfully in a hazardous situation. Such knowledge might include beliefs about prescribed fire operations such as rate of spread, association of high-intensity fire behavior with heavy fuels, ignition patterns, briefings, and training. Shared beliefs provide an image of the "true situation" managers face when prescribing fires in flammable wildland vegetation.

These normal beliefs are fundamental to the concept of an accident caused by an individual. Accidents, within this perspective, are defined again as unwanted events caused by individuals who do not adequately use known safeguards to account for and cope with the hazardous situation they face.

People adhere to a set of precautionary rules that are consistent with accepted beliefs about the hazards of prescribed fire. Precautionary rules take the form of laws, practices, and policies that guide the use of prescribed fire. Wide acceptance of these precautions is possible because people tend to think that a violation of norms can cause undesired consequences. For example, individuals try to be particularly careful when applying prescribed fire to meet resource management objectives. They have learned to

associate careless use of fire as one cause for an outbreak of a catastrophic wildfire. Individuals usually think that a violation of precautionary rules may unleash a conflagration.

Stage II--Incubation Period

A prescribed fire disaster occurs when culturally accepted beliefs and norms are found to be inadequate or inaccurate. This cultural collapse reveals a serious discrepancy between the perceptions of prescribed fire hazards and the way prescribed fire hazards really operate. This discrepancy, however, does not arise instantaneously. There is instead an "incubation period" in which a series of events accumulate unnoticed--events that are inconsistent with the normal image of prescribed fire hazards. Prescribed fire safety measures are thought to be an adequate response to known threats presented by hazards, but vague and undelineated dimensions of the fire hazard problems are often at work and may remain outside the awareness of many individuals. Widespread fuel accumulation, coupled with the extensive use of prescribed fire in many new situations, constitutes just such a discrepant event. Such discrepant events can only build up unnoticed if they remain unknown to most people or if they are known but misunderstood in such a way that their consequences remain unknown.

A distinction between accidents and disasters is fundamental to this analysis. According to Turner, accidents are best distinguished from disasters on the basis of the number of links in a causal chain that leads to a failure of precautionary actions. Accidents occur when an error in judgment or knowledge leads almost immediately to a breakdown. A very short incubation period precedes accidental events, because the breakdown occurs in response to a failure to heed a warning that presents itself immediately before the accident. Failure to keep a kite free from high voltage transmission lines is an example of how such an "accidental" fire could start. Thus, accidents represent inappropriate responses to routinely recognizable warnings.

Incubation periods for prescribed fire problems could involve a far longer series of errors that may take years to accumulate and that may involve vast areas of land. The character of the triggering error, even if defined as an accident, is relatively insignificant in the context of the network of predisposing errors. People often refer to the importance of such predisaster situations with comments such as: "It would have happened sooner or later anyway," or "It was the final straw that broke the camel's back."

Stage III--Precipitating Undesirable Event

The shock of a precipitating incident is necessary to redirect attention to the accumulation of unnoticed errors in the incubation period. The power of the precipitating event to transform beliefs and precautionary rules regarding prescribed fire depends upon total surprise. Although a disastrous prescribed fire may have been predicted by heretics or prophetic dissidents, general recognition of the underlying process that caused significant fire losses will not occur unless it is unexpected. A transformation of culturally accepted prescribed fire beliefs and policies will occur only if a disastrous event is totally unpredictable.

Stage IV--Onset

The outbreak of a disastrous prescribed fire is followed immediately by the onset of unanticipated consequences that force practitioners to face realities not accounted for by existing prescribed fire measures. The onset of the prescribed fire disaster is represented by high-intensity burning, rapid rates of spread, large area burned, and lives and property lost.

Stage V--Suppression, Rescue, and Salvage

The onset of a disastrous prescribed fire is accompanied or followed by fire suppression, rescue, and salvage operations. Major features of a failure of existing beliefs and precautions become evident as people go about meeting immediate problems of suppression, rescue, and mopping up.

Stage VI--Full Cultural Readjustment

After the agency has recovered from the immediate impacts of the onset of a disastrous prescribed fire, an investigation usually is conducted to determine why standard precautions failed. Cause-and-effect relationships are reexamined in the light of new knowledge revealed by the failure of culturally accepted precautions. Experts and others with diverse interests are given an opportunity to present interpretations of the disaster along with proposals for reducing the likelihood of reoccurrence for such an event.

MANAGEMENT IMPLICATIONS

Increased recreational use of wildlands and expanding prescribed fire programs make it likely people will have a greater chance of encountering fires in the future. Survey results indicated that the public generally has not perceived any direct threats to their safety from prescribed fires in parks and wildernesses and that managers have not reported any serious safety problems in administering sizable and complex prescribed fire programs. The successful safety record produced by park and wilderness managers is to be commended.

Although some managers may tend to feel that if it isn't broken (current safety measures), don't fix it, obviously there is no room for complacency in ensuring the safety of visitors and agency personnel. We have noted that serious consequences may suddenly arise when injurious causes accumulate unnoticed during a prolonged incubation period. Park and wilderness managers have the serious responsibility of analyzing and evaluating current

safety programs that are so vital to the successful continuance of prescribed fire activities. Managers must prepare both visitors and agency personnel to avoid accidents and disasters.

Preventing Accidents

Survey results indicated that managers are employing a variety of measures to provide for the safety of visitors and personnel. Closures, signing, brochures, newsletters, interpretive programs, media reports, hiker registration, and public involvement in planning (in-Service and general public) were commonly mentioned as practices used to make people aware of possible fire hazards. Closures are accomplished through signing or wilderness/backcountry permit systems. One respondent reported that media coverage tended to attract crowds, whereas another said burning by planned ignitions was done before the visitor season or only in remote areas. Another effective practice is the use of on-the-ground contacts. This is done by roving interpreters who explain the purpose for burning and necessary safety precautions. Visitor contacts also can occur at such conventional places as entrance stations, ranger stations, businesses, bulletin boards, and registration desks; therefore, it is necessary to keep current information at nearby facilities. Evacuation was cited several times as a means to remove visitors from danger.

Safety procedures to prevent accidents can be summarized as follows:

- Interpretation is an effective means to educate people about safety, particularly when visitor contact is made at an ongoing fire.

- Consistent, accurate monitoring and evaluation of fire behavior provides the basis for developing contingency plans, contacts, and briefings that ensure public and personnel safety.

- Inform surrounding residents and visitor services about fire occurrences, status, and actions. Keep in-Service public and neighboring agencies informed by newsletters, memorandums, phone calls, and meetings.

- Use only fully qualified personnel to conduct prescribed fires, and emphasize safety training, proper clothing, physical fitness, escape routes, and briefings.

- Use caution signs on roads and trails to warn travelers that a fire is in progress and list procedures to avoid hazards. Personnel stationed on roads and trails should make visitor contacts to prepare people to travel in a safe manner.

- Develop maps and brochures that instruct and inform people about safety hazards and precautions.

Wildland fire hazards and human survival precautions have been reviewed on a worldwide basis (Davis and Mutch 1983). A safety brochure has been adapted from this review (see appendix) that describes travel and evacuation precautions, entrapment procedures, and fire survival procedures in vehicles and buildings. Recreationists and wildland homeowners are the intended audiences for this brochure.

Preventing Disasters

The prevention of accidents is only <u>part</u> of the manager's total safety responsibility, but it is the area that usually receives <u>all</u> of the manager's attention. Understanding the stages in the development of a disaster and becoming vigilant about subtle changes in prescribed fire programs can place the manager in the enviable position of making timely safety adjustments to avoid the surprise and shock of a full-fledged disaster.

An old adage simply states that nothing can be seen if you don't know what you are looking for. Five reasons best explain how events can accumulate unnoticed and remain imperfectly understood by managers during the incubation stage leading to a disaster:

1. People are generally reluctant to fear the worst, with the result that they dismiss evidence of hazardous conditions or fail to notice warning signs of accumulating danger.

2. Violation of prescribed fire policies and rules may come to be accepted as normal when people obtain misinformation or fail to learn appropriate beliefs and norms.

3. Information overload in complex situations may be so much of a problem that people fail to attend to signs of danger or observe precautionary actions.

4. People's attention may be directed from warning signs by lesser or more immediate concerns. For instance, attempts to meet designated targets and objectives may divert attention away from a more basic need to conduct prescribed fires in a safe manner.

5. Prescribed fires that escape at rather frequent intervals may tend to elicit attitudes suited to routine accidents rather than disasters.

The significance of one change in the incubation period that may not have been recognized fully is the fact that we now manage <u>two</u> types of prescribed fires: those from planned ignitions and those from unplanned ignitions. Have we adjusted safety procedures to accommodate some of the key differences posed by unplanned ignitions (longer duration fires, often higher intensity fires, more remote fire locations, uncertain location of recreationists, and absence of control lines), or have we merely transferred traditional prescribed burning safety practices to the relatively recent use of unplanned ignitions? A failure to tailor safety precautions to the specific characteristics of prescribed fires from unplanned ignitions could trigger a disaster.

How close have we been to a disaster already, only to have it unknowingly averted by the fact that not all causal links in the disaster chain were in place? Have we been lucky so far that a disaster has not occurred? For example, a recent situation in a western wilderness demonstrated how bypassing fundamental precautions could have produced disastrous consequences to personnel. Numerous prescribed fires started by lightning had been burning for several weeks when conditions changed and new starts were suppressed due to increasing fire danger throughout the Region. Smokejumpers and ground personnel were dispatched to suppress wildfires in the wilderness that were intermingled with the prescribed fires. Although some of the wildfires were located downwind from the prescribed fires, suppression personnel were not briefed in advance on the status of free-burning prescribed fires in their area. If strong winds had developed at this time, the interaction between prescribed fires and wildfires could have posed serious safety threats to suppression personnel. These people later voiced strong concerns for the lack of regard for their safety and welfare.

The recreationist scenario presented earlier and the case example involving suppression personnel accent the need for park and wilderness managers to critically evaluate the adequacy of current safety measures of prescribed fire programs resulting from planned and unplanned ignitions. Safety issues, concerns, and results must be carefully monitored and evaluated to ensure timely revisions of accident prevention programs and to develop contingency plans to avert disasters under "worst case" conditions. Understanding the stages of a developing disaster should help managers become more observant about subtle warning signals during the incubation stage.

SUMMARY

Prescribed fire activities have been increasing in frequency and complexity in North America in recent years. Prescribed fire programs also have included cases of serious loss of lives and property since 1979. Although often taken for granted, prescribed fires can produce potentially hazardous situations. The very continuance of such programs depends closely on the care and skill we bring to the task of safeguarding people from injuries. The terms accident and disaster were defined, and the six stages associated with a prescribed fire disaster were listed to help people prevent future safety problems. Finally, adjustments were described that must be made to ensure the safety of recreationists and agency personnel.

The message is a clear one--we must always maintain a healthy respect for fire, apply the fundamentals that we know so well to prevent accidents, and be alert toward <u>changing</u> conditions to prevent disasters.

ACKNOWLEDGMENTS

We recognize Professor Robert G. Lee, University of Washington, for his applications of a rather extensive body of natural disaster literature to the fire problems of the urban-wildland interface. This disaster theory is just as relevant to improving safety adjustments of prescribed fire programs. We thank Bob Lee for helping to focus new insights on the prevention of fire-related accidents and disasters.

We also acknowledge numerous respondents in the United States and Canada for their assistance in completing a fire safety survey form. This paper is especially dedicated to these people and their counterparts throughout North America who successfully administer complex prescribed fire programs with strong personal commitment to public and personnel safety.

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APPENDIX A: Fire Safety Brochure

WILDLAND FIRE HAZARDS: SAFETY AND SURVIVAL PRECAUTIONS FOR RECREATIONISTS AND HOMEOWNERS

FIRE EXPOSURE

Since recreational and residential use of wildlands is increasing, the general public needs to be prepared to safely encounter prescribed fires that may have been allowed to burn in national parks and wildernesses or wildfires. This brochure presents information about fire hazards, fire behavior, and survival principles to help recreationists and homeowners prevent injury and death.

There are five possible ways in which people can be injured or killed by fire:

- The body's heat regulation mechanism fails
- The body is burned
- The lungs are seared by superheated gases
- People are overcome by smoke and suffer from lack of oxygen
- People are poisoned by carbon monoxide or other toxic gases.

FIRE BEHAVIOR

The science of fire behavior describes how fires burn in relation to the controlling factors of fuel, weather, and topography. No two fires are exactly alike, as there are almost infinite combinations of fuel, weather, and topographic situations. A cardinal rule of fire safety is to base all actions on current and expected behavior of fires. Will the fire spread slowly or quickly? Will it remain on the ground or burn into the crowns of shrubs and trees? Or will wind currents carry burning embers beyond the main fire, causing the fire to burn hotter, faster, and producing new fires in unexpected places? Several early warning factors help signal the onset of "hotter" and "faster" burning conditions:

Fuel

- Flashy fuel (dead grass or long pine needles)
- More fuel
- Drier fuel
- Dead fuel
- Aerial fuel (combustible material suspended in the crowns of high shrubs and trees).

Adapted from Davis, Kathleen M.; Mutch, Robert W. Wildland fires: dangers and survival. In: Auerbach, Paul S.; Geehr, Edward C., eds. Management of wilderness and environmental emergencies. New York, Toronto, and London: Macmillan; 1983: 451-480.

Weather

- Faster winds or sudden changes in speed and direction
- Unstable atmosphere (indicators: gusty winds, dust devils, and good visibility)
- Erratic and strong downdraft winds from towering cumulus clouds and dry thunderstorms
- Higher temperatures
- Drought conditions
- Lower humidities.

Topography

- Steeper slopes
- South- and southwest-facing slopes
- Gaps or saddles
- Chimneys and narrow canyons.

Fire Behavior

- Burning material rolling downhill and igniting fuel downslope
- Spot fires occurring ahead of main fire
- Individual trees "torching" out
- Shrubs or trees burning in a crown fire
- Smoldering fires over a large area
- Many fires starting simultaneously
- Fire whirls causing spot fires and erratic burning
- Intense burning with flame lengths greater than 4 feet
- Smoke column dark and massive with rolling, boiling vertical development
- Lateral movement of fire near base of steep slope.

Extreme caution should be used when moving downhill toward a fire that can suddenly burn swiftly uphill. Also, care should be used when there is unburned fuel between you and fire, or when walking in difficult terrain, darkness, or unfamiliar country.

The first step a person should take upon encountering a wildland fire is to review the principles and warning signals, sizing up the situation in terms of fuel, weather, and topography factors and observed fire behavior. After making an estimate of its probable direction and rate of spread, travel routes can be planned that avoid life hazards.

TRAVEL AND EVACUATION PRECAUTIONS

The following rules have been adapted from the "Ten Standard Orders" for firefighters to remind people of safety precautions while traveling near fire or evacuating from fire hazards:

1. Choose a leader at the outset who gives clear instructions and maintains control of the group.
2. Continually observe changes in speed and direction of fire and smoke to choose travel away from fire hazards.
3. Plan an alternate route in case fire suddenly changes direction and threatens you.
4. Keep aware of fire movement while traveling to avoid entrapment.
5. Be alert, keep calm, think clearly, and act decisively to avoid panic and to avoid injury by rolling or falling debris.

ESCAPE AND ENTRAPMENT PROCEDURES

In some instances there may be no chance to avoid a fire. When entrapment is probable, injuries or death may be avoided by following these procedures:

1. Do not panic. If fear becomes overwhelming, judgment is seriously impaired and survival becomes a matter of chance.
2. Do not run blindly or needlessly. Unless the path of escape is clearly indicated, do not run. Move away from the flanks of the fire, traveling downhill where possible. Conserve your strength.
3. Enter the burned area. Do not delay. If escape means passing through the flame front into the burned area, do so when flames are less than 3 feet deep and you can see clearly through them. Cover exposed skin, take several breaths, and move through the flame front quickly.
4. Burnout. If unable to enter the burned area, ignite grass and other fine fuels between you and the fire edge. Step into this burned area and cover as much of your exposed skin as possible. This action will not be effective in heavier fuels that burn for a long time.
5. Regulate breathing. To avoid inhaling dense smoke, take shallow, slow breaths close to the ground.
6. Protect against radiation. Shield yourself from heat rays by seeking a shallow trench, crevice, large rock, lake, stream, large pond, vehicle, or building. Don't seek refuge in elevated water tanks. Wells and caves generally should be avoided because oxygen may be quickly used up in these restricted places. Cover exposed skin with clothing or dirt.
7. Lie prone. In an emergency, lie flat with head down on an area that will not burn. A person's chance of survival is greater in this position than if overtaken by fire when standing upright or kneeling.

SURVIVAL IN A VEHICLE

If trapped in a vehicle by fire, the following steps will enhance survival:

1. Do not drive through dense smoke
2. Park away from heaviest vegetation
3. Turn headlights on and ignition off
4. Do not leave the vehicle
5. Roll up windows and close air vents
6. Get on the floor and cover with blanket or coat, if possible
7. Stay in the vehicle until the main fire passes.

While it is frightening to be trapped in a car by fire, it is almost certain doom to attempt escape by running from fire. A few facts may prevent panic:

1. Engine may stall and not restart
2. Convection currents may rock vehicle
3. Smoke and sparks may enter the vehicle
4. Temperature will increase inside the vehicle
5. Metal gas tanks and containers rarely explode.

SURVIVAL IN BUILDING

Fire protection agencies encourage people to evacuate homes and buildings, rather than staying behind to fight the fire. When threatened by an approaching fire, however, people may find a safer refuge in buildings than in the open. Safe refuge in buildings depends on the construction materials and reduction of fuels around the structure. A building usually offers protection during the passing of fire, even if it ignites later, because it shields against radiant heat and smoke. Take the following precautions before fire approaches:

1. Remove combustible items from around the house.
2. Close doors, windows, and vents. Turn on light in each room for visibility in dense smoke.
3. Place water in containers to fight fire. A wet mop can be used to extinguish sparks or embers inside the building.
4. Locate garden hoses so they will reach any place on the house.
5. Use portable gasoline-powered pumps to take water from a swimming pool or tank.
6. If you have a combustible roof, wet it down or turn on any roof sprinklers.
7. Back car in the garage and shut car doors and windows. Disconnect the automatic garage door opener (in case of power failure you could not remove the car). Close all garage doors.
8. Close windows and doors to the house to prevent sparks from blowing inside. Close all doors inside the house to prevent draft. Open the damper on your fireplace to help stabilize outside-inside pressure, but close the fireplace screen so sparks will not ignite the room.
9. Turn off pilot lights.
10. Take down drapes and curtains. Close all venetian blinds or noncombustible window coverings to reduce the amount of heat radiating into your home.
11. Go inside the house as the fire front approaches.
12. After the fire passes, check inside and outside the house for fires. It may be necessary to exit a burning building following passage of the main fire front.

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FIRE SUPPRESSION FOR WILDERNESS AND PARKS: PLANNING CONSIDERATIONS

Richard J. Mangan

ABSTRACT: Planning for wildfire suppression in wilderness and parks must encompass existing management policies, the physical character of the area, and specific suppression actions. In order to judge whether objectives have been met, monitoring and evaluation standards must be established.

INTRODUCTION

Since naturally occurring fires were first allowed to burn in the Sequoia and Kings Canyon National Parks in 1968, park and wilderness fire managers have spent much time and effort preparing plans that allow unplanned ignitions[1] to burn in prescription. They have prepared detailed fire histories, fuel inventories, and vegetative maps; developed monitoring and evaluation plans; and constructed conflict decision matrices. More than 18 wilderness areas with more than 9 million acres (3.6 million ha) of national forest land and 16 national parks with nearly 7 million acres (2.8 million ha) have approved fire management action plans (Kilgore 1982). Since these programs began, more than 1,200 lightning-caused fires have burned more than 190,000 acres (≅76 900 ha) in prescription.

As the 1,200 prescribed fires from unplanned ignitions were occurring, other fires ignited within the same fire management area were declared wildfires and burned out of prescription. One of the most notable of these was the Mortar Creek Fire in the River of No Return Wilderness of Idaho; it burned 65,300 acres (≅26 400 ha) in 1979. Although a prescribed fire meets management objectives and a wildfire does not, one factor remains constant in our approach to both: we strive to minimize the signs of our activities in wilderness areas and parks.

Fire suppression activities often leave more obvious, and longer lasting, signs of human activity than do actual fires, prescribed or wild. Tractor firelines, felled snags, helispots, and areas clearcut of all standing trees and snags remain as unacceptable memorials to our suppression efforts.

Acknowledging that many ignitions in wilderness and parks will continue to be declared wildfires means a greater emphasis must be placed on planning and on developing strategies and techniques that meet the wildfire suppression objectives. At the same time, we must continue to minimize the adverse impacts our suppression actions have on resources. Wilderness and park resources are unique; therefore, fire suppression planning in wilderness and parks must accommodate their special character during each phase of suppression action.

MAJOR CONSIDERATIONS

Managers preparing a fire suppression plan for parks and wilderness must consider the following questions:

1. What management policies must we consider when suppressing wildfires?

2. What physical factors must be considered in planning the fire suppression?

3. What specific actions should we take in suppressing wildfires to minimize the adverse effects of suppression activities?

Management Policies

The public's expectations for conditions in parks and wilderness are generally different than those they have for general forest lands. Management objectives in wilderness and parks emphasize the naturalness and recreation opportunities of the areas. With these management emphases, it is apparent that "business as usual" in fire suppression activities is not acceptable. Planning acceptable fire suppression actions requires a full understanding of the goals and objectives that management has set. These can be classified as management direction, limitations, priorities, and budgetary concerns.

General direction.--The intent of the Wilderness Act of 1964 is to ensure that areas are managed so that the "forces of nature shall dominate with the sign of man's activity not apparent." Many parks include wilderness areas or manage nonwilderness areas in a similar manner. It is essential for the line officer and fire manager to agree upon the role and direction that fire suppression will play in

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[1]Editors' note: please refer to the Foreword for comments on prescribed fire terminology.

meeting such management objectives. The conditions under which "confine, contain, and control" suppression strategies are justified must be specified.

Limitations.--Motorized equipment is excluded from all wilderness and some parks except in emergencies. Some wilderness areas restrict motorized equipment even in emergencies unless a responsible line officer approves. The conditions under which the mechanized equipment may be used as part of the fire suppression planning process should be established.

Priorities.--The priorities for suppression may also vary, depending upon the management emphasis of the area being protected. Although nearly all agencies give the protection of human life top priority, there is little consistency in priorities beyond that point. Capital investment improvements, threatened and endangered species, historical or cultural sites, and Native American religious sites are among the many concerns that compete for fire suppression priority status. It is important to assign and understand these priorities before wildfire ignition occurs if fire suppression action is to be effective.

Budget.--Budget constraints are also an important factor in planning fire suppression action. The number and type of initial attack forces available, the dollar limitations imposed by specific agencies on suppression actions, and the emphasis on cost efficiency versus resource damages must all be incorporated into fire suppression planning.

Physical Factors

The physical aspects of fire suppression in wilderness and parks are similar to those in general fire suppression. Fire history, fuel accumulation, weather, topography, and vegetative patterns must be evaluated as they relate to fire suppression and the preferred management direction. Once this has been done, it is possible to consider specific suppression actions.

Suppression Actions

A number of factors make fire suppression in parks and wilderness different than in a general forest environment. These are access, equipment limitations, and social and political concerns.

Access.--All wilderness and many areas within parks are unroaded. Trails are often the only transportation system. Because smokejumper and helicopter crews are available to most national forests and national parks, a lack of roads would not seem to present any difficulty. There is, however, an increasing tendency, especially in the West, to restrict the use of aerial-delivered firefighters in these areas. This practice may enable fires to become larger before they are reached by initial attack forces. It will also complicate the task of reinforcing the initial attack, which may again increase fire size. With larger fires comes the need for fire camps to feed and supply fire suppression crews. Again, limited access may necessitate the use of spike camps rather than the large fire camps that normally accommodate firefighters. Careful planning of fire campsites can ensure minimum adverse impact on the wilderness and park resources while meeting the needs of fire suppression forces.

Equipment limitations.--Over the past 50 years, our fire suppression actions have come to depend more and more on mechanized equipment. Dozers, chainsaws, and pumps have become commonplace in firelines throughout the forest and rangelands; however, this equipment may not be acceptable for some fire suppression actions in parks and wilderness. Experience with past wildfires has shown that suppression actions (building firelines, cutting snags, and mopping up) have caused a longer-lasting adverse impact on the resource than the wildfire itself; therefore, such activities are now often limited. Good fire suppression planning should identify conditions and locations where the use of equipment is necessary to achieve fire protection objectives, as well as those times and places where equipment use should be totally or partially restricted.

Social and political factors.--None of the lands that we protect from wildfire are watched as carefully by the public as parks and wilderness. The level of public concern is extremely high when fires occur in these areas, whether as prescribed fires or wildfires. The land manager is pressured from all sides to take a number of steps that may be contrary to management direction. Some will urge that we compromise our values to stop the "ravages of wildfire"; others tell us to allow fire to "do its thing," even though it may be clearly out of prescription. In addition, threats to public safety (real or imagined) may become important in heavily used recreation areas or along well-traveled trails. Good fire suppression planning for a park or wilderness must develop a program that presents a strong positive picture to the public of what we are doing and why. Failure to do so may cause long-lasting impacts on our ability to manage fire in these areas.

IMPACTS OF FIRE SUPPRESSION

Three major classes of fire suppression impacts are of concern:

1. The physical impact consists of felled trees and snags, construction of helispots, fire camp damage, retardants in the water, excessively wide or deep firelines, and dozer trails into the fire site. Many of these impacts are long term.

2. The visual impact includes rocks and vegetation covered by retardant, areas of all trees or snags felled, fresh-cut stumps, firelines, pack string trails, and litter left on a fire or in a fire camp. Some of these impacts are of short duration, but others are long term.

3. The audio impacts of suppression action are short term but often cause the most immediate adverse reaction from wilderness and park users. Helicopters, air tankers, chainsaws, and pumps seriously interrupt the peace and tranquility of a park or wilderness setting.

CONCLUSION

Major considerations in park and wilderness fire suppression planning are management policies, specific physical features in parks and wilderness, and specific ways of minimizing fire suppression impacts. Problems with access, equipment limitations, and public attitude further complicate the process. Steps that may minimize the complexity of suppressing wildfires while reducing impacts of fire suppression actions include (1) obtaining preapproval for the use of mechanized equipment in specific circumstances considered appropriate and necessary; (2) preparing special guidelines for fire suppression actions within parks and wilderness; (3) conducting special training (for example, Wilderness Fire Boss training); and (4) developing a followup process to monitor and evaluate fire suppression actions.

A well-prepared fire suppression plan for a park or wilderness (1) meets the management objectives of the area; (2) considers the physical aspects of the area that will affect fire suppression efforts; (3) has fire suppression actions planned for the wildfires that occur; and (4) establishes monitoring/evaluation standards to judge whether fire suppression efforts have met the management and protection objectives of the area.

The unique and special characteristics of wilderness and parks require modifying normal wildfire suppression actions. Accepting such modifications may, however, increase costs and burn more area than would normally be acceptable in a general forest. The adjustments we make in order to "lay a light hand on the land" are essential if the spirit of the wilderness and parks is to be maintained.

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FIRE BEHAVIOR PREDICTION TECHNIQUES FOR PARK AND WILDERNESS FIRE PLANNING

Larry D. Keown

ABSTRACT: Knowledge and technology that have become available in the past 32 years have made possible a number of fire behavior prediction techniques. This discussion of fire behavior prediction techniques, fire behavior components, and tools applicable in wilderness and park fire planning provides the fire planner with a useful summary of information essential to making fire behavior predictions.

INTRODUCTION

The first comprehensive text on fire behavior prediction techniques was published in 1951 by Barrows. Although Barrows emphasized fire behavior as it relates to fire suppression and safety, he also developed estimating guides for weather, topography, fuels, and fire behavior rating. It was not until 1972 that Rothermel (1972) published his mathematical fire spread model, which has become the recognized standard on fire behavior. Albini (1976) developed a set of nomographs based on Rothermel's fire model and a set of 13 standard fuel models. These easy-to-use graphical calculation aids soon became the basis for predicting fire behavior because their numerical outputs were readily usable by fire managers. In 1979, a microchip for predicting fire behavior with the TI-59 hand-held calculator was developed; an innovation that greatly expanded the field application of Rothermel's fire spread model. Today, the Northern Forest Fire Laboratory (Andrews, in preparation; Burgan and Rothermel, in preparation) has developed a sophisticated computer program that increases the versatility and speed of Rothermel's fire spread model for many fire management applications. In addition, a 2-week course offered by the National Advanced Resource Technology Center at Marana, Ariz., trains land managers in state-of-the-art fire behavior prediction techniques and applications. Since 1951, knowledge that can be applied to fire behavior prediction techniques has become increasingly available, particularly in the last 10 years. Rothermel's comprehensive text (1983) is the culmination of this exhaustive research and its application. All the research tools available to land managers, however, will not replace basic fire behavior knowledge and experience. This prerequisite is necessary to ensure valid input data, interpretation of output, and validation of the results. I encourage those using the techniques outlined in this paper to attain the necessary experience and observe basic fundamentals of fire behavior.

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FIRE BEHAVIOR PREDICTIONS IN FIRE PLANNING

Establishing Historical Fire Behavior

Fire behavior predictions are invaluable in defining historical fire behavior for a wilderness or park. Predictions compared with actual fires and vegetative patterns can aid the fire planner in what to expect in the future. This procedure, called "gaming," allows the fire manager to estimate potential fire size, fire intensity, rates of spread, and fire effects. For example, in a 1978 study (Keown 1978), I based predictions of crown fires in ponderosa pine/Douglas-fir (*Pinus Ponderosa/Pseudotsuga menziesii*) ecological land unit (Selway-Bitterroot Wilderness) on predicted fireline intensity. Descriptions of fuels by Aldrich and Mutch (1972) indicated that this ecological land unit produces relatively abundant vegetation and that fuel accumulations are significant because of past fire protection practices. Through fire scar analysis, these areas were determined to have experienced short-interval fires of low-to-moderate intensity and burning primarily on the ground (Aldrich and Mutch 1972). Armed with such information, the fire manager can recreate what occurred and anticipate expected changes.

Contingency Planning

Contingency planning for wilderness and park fire planning is much like strategy planning for a wildfire. In other words, if the fire exceeds prescription criteria, contingency planning describes what can be done to bring the fire back into prescription. Fire behavior predictions can aid the fire manager in anticipating "what if" situations. Such planning is imperative in maintaining professional wilderness and park fire management programs concerned with public safety and protection of wilderness values.

Fire Effects

Fire behavior predictions lend themselves well to predicting some aspects of fire effects. Knowledge of potential intensities, crowning, and topographic and weather considerations allows the fire planner to predict burn patterns and in some cases resulting vegetation. Predicting fire effects on air quality and visitor safety is also possible with these techniques. For example, predicted high-intensity fires with massive smoke production in an area frequented by daily inversions could significantly degrade air quality. Such predictions are useful in the initial decisionmaking process where fires are small and can be easily suppressed.

Fire behavior predictions can play a significant role in assessing potential workload, and thus are critical when workload is constrained by budget, personnel, or logistical limitations. Predictions of the numbers of fires and their potential size and intensity can help the fire planner to decide whether to suppress a fire or to designate it a prescription fire. Decision analysis may include monitoring, suppression, evaluation, prescription constraints, or economical considerations.

Prescription Development

The design of wilderness and park fire management prescriptions requires fire behavior predictions. Comparing National Fire-Danger Rating components and indices (Deeming and others 1977) with fire behavior predictions allows the fire manager to test prescriptions and determine their significance. Of particular importance are fires near prescription limits (for example, boundaries) or impending severe fire weather, either of which may pose future problems. For example, a fire ignition within National Fire-Danger Rating System prescriptions that is projected to spread out of the fire management area, based on fire behavior predictions, should receive an appropriate suppression response. Fire behavior predictions may also confirm constraints on prescription variables such as air quality, protection of sensitive features, visitor safety, or fire size.

FIRE BEHAVIOR COMPONENTS AND THEIR APPLICATION

A number of fire behavior prediction components are available to the fire planner for wilderness and parks fire management planning. Such components include flame length, fireline intensity, rate of spread, probability of ignition, spotting distance, crowning potential, and National Fire-Danger Rating components and indices.

Flame Length and Fireline Intensity

Albini (1976) defines fireline intensity as the amount of heat released per unit of fire for each unit of length of fire edge. He describes flame length as an alternative form of quantifying fireline intensity. Both fireline intensity and flame length are useful to the fire planner in quantifying how hot a fire will burn. For example, these variables are relevant to crown scorch, crowning potential, resistance to control, and fire effects for contingency, fire effects, and prescription planning. The following tabulation (from Rothermel 1983) relates flame length and fireline intensity to specific fire behavior.

Flame length		Fireline intensity		Interpretation
Feet	Meters	Btu/ft/s	Kcal/m/s	
<4	<1.2	<100	<82.6	Fires can generally be attacked at the head or flanks by persons using handtools. Hand line should hold the fire
4-8	1.2-2.4	100-500	82.6-413.4	Fires are too intense for direct attack on the head by persons using handtools. Hand line cannot be relied on to hold the fire. Equipment such as dozers, pumpers, and retardant aircraft can be effective.
8-11	2.4-3.3	500-1,000	413.4-826.8	Fires may present serious control problems--torching out, crowning, and spotting. Control efforts at the fire head will probably be ineffective.
>11	>3.3	>1,000	>826.8	Crowning, spotting, and major fire runs are probable. Control efforts at head of fire are ineffective.

Flame length and fireline intensity prediction techniques.--The equations for flame length and fireline intensity use fuel model; fuel moistures; windspeed; percent slope; and, in some fuel models, live fuel moisture as inputs. Many systems predict flame length and fireline intensity and include nomographs (Albini 1976), hand-held calculators (Burgan 1979), and computers (Andrews, in preparation; Burgan and Rothermel, in preparation). Albini's (1976) nomographs and the hand-held calculator (Burgan 1979) allow the use of site-specific environmental data to rapidly assess modeled or going fires. In addition, Albini (1976) describes methods for calculating duff burnout and crown scorch and discusses particulate production using flame length and fireline intensity.

The BEHAVE fire behavior prediction and fuel modeling computer system is currently being field tested by many Federal and State agencies. The system allows the fire manager to custom build a fuel model, test the model, and use it with site-specific environmental conditions. The user can also predict fire behavior over a range of variables such as fuel moistures and windspeeds. Combinations of the input data produce a tabular listing of fire behavior variables selected by the user; these include fireline intensity and flame length. Designed for site-specific application, the program allows the fire planner to create many scenarios rapidly. The system is ideal for gaming historical or hypothetical fires in a wilderness or park.

Andrews' and Rothermel's (1982) graphic interpretations of fire behavior are useful in displaying results of fire behavior calculations for flame length and fireline intensity (fig. 1).

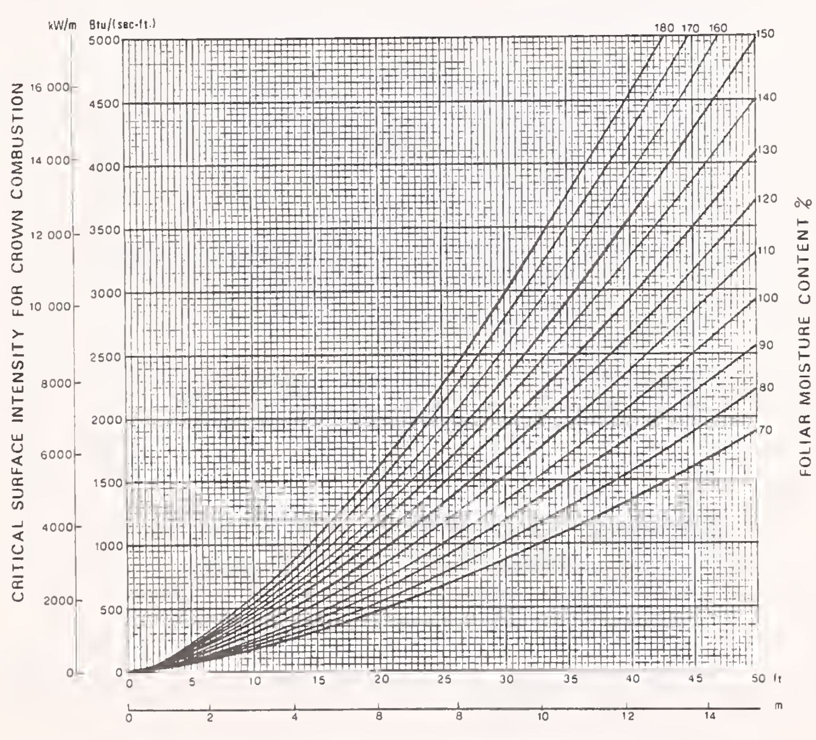

Figure 1.--Charts for interpreting wildland fire behavior characteristics.

Rate of Spread, Perimeter, and Area Growth

Fire behavior predictions are also useful for projecting fire size, perimeter length, and area growth. Applications include projecting spot fire growth and subsequent size, amount of fire control resources required for containment, contingency planning, workload analysis, and projections of final fire size. Such variables are used in wilderness and park fire planning decision analysis to project how large a prescription fire may become and if it will meet management objectives. Some fire plans have used fire size as a prescription criteria, particularly in small fire management areas where large fires are not acceptable and will not meet management objectives.

Rate of spread, perimeter, and area growth prediction techniques.--Calculations for rate of spread use fuel model, fuel moistures, windspeed, and percent slope as inputs. Projections for perimeter length and fire size use rate of spread and projection time as inputs. Prediction techniques for rate of spread include the use of nomographs (Albini 1976), hand-held calculators (Burgan 1979), and the BEHAVE system (Andrews, in preparation). Projections of perimeter length and fire size can be accomplished using the TI-59 calculator (Burgan 1979) and the BEHAVE system (Andrews, in preparation). Further projections for spread distance and map distance can be made using the TI-59 calculator and BEHAVE system with projection time, rate of spread, and map scale as added inputs.

Probability of Ignition

Probability of ignition is an important fire behavior variable when projecting fire spread. Probability of ignition measures the probability of a firebrand initiating ignition. It should not be confused with ignition component, which is a component of the National Fire-Danger Rating System and rates the chances of an ignition becoming a detectable fire. Using probability of ignition includes assessing fire spread through spotting (not accounted for in Rothermel's [1972] fire spread model), planning burnout operations, and the ease of ignition of fine fuels. For example, if the probability of ignition indicates low spotting potential but easy ignition for firing crews, a fire manager could use this information to establish the most opportune time to begin a burnout.

Probability of ignition prediction techniques.--Tabular calculations for probability of ignition are available in Rothermel's (1983) text on predicting fire behavior. Probability of ignition uses fine fuel moisture, air temperature, and shading as inputs.

Crowning Potential

Rothermel (1983) states that the conditions under which crown fires are likely to occur are those that will produce fireline intensities in surface fires beginning in the 500-1,000 Btu/foot/second range. Such information for wilderness and park fire planning can be used to project crown fire potential, smoke production, contingency planning needs, and fire effects such as vegetative mosaics.

Crowning potential prediction techniques.--Techniques for predicting crowning potential are offered by Fahnestock (1970) and Rothermel (1983). Fahnestock's (1970) rating system rates crowning potential on a scale of 0 to 10. Input information includes foliage, crown density, ladder fuel presence, tree spacing, and resinous properties of foliage. Rothermel (1983) describes an unpublished report by Martin E. Alexander that "identifies the surface fireline intensity necessary to cause the crown combustion based upon the height to the live crown base and foliar moisture content" (fig. 2).

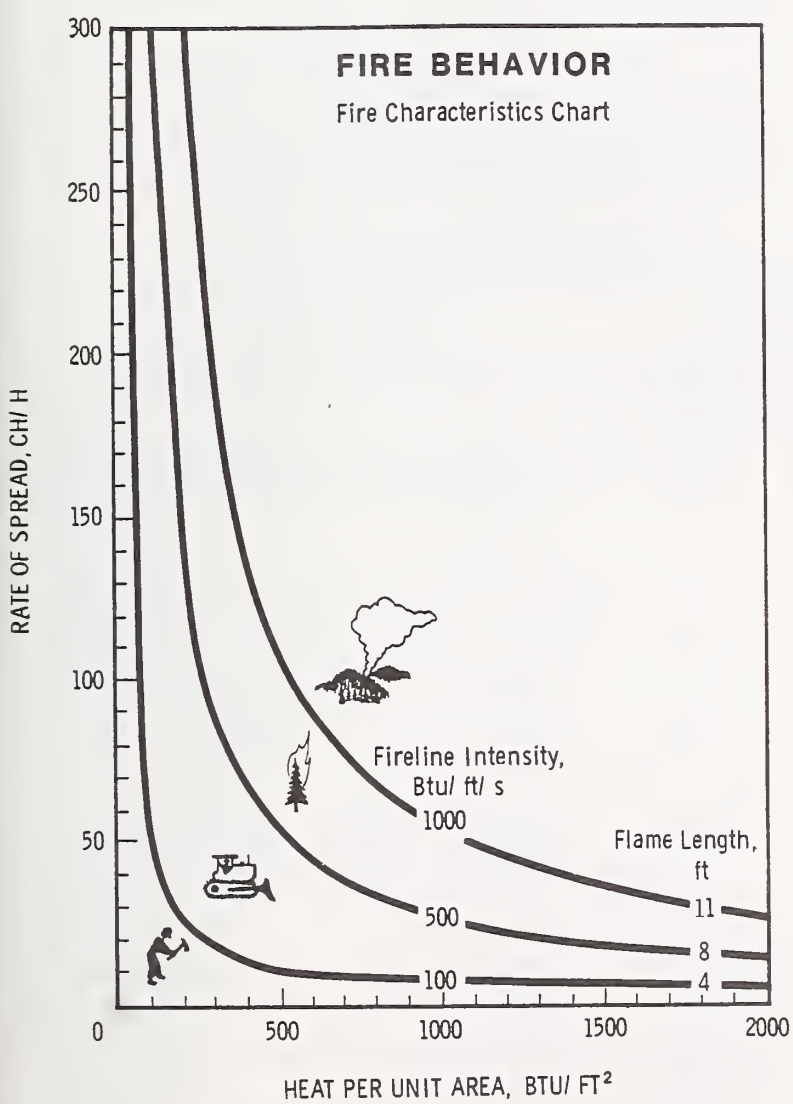

Figure 2.--Surface intensity required for crown combustion.

Spotting Distance

Albini (1979) describes a model to predict the maximum distance from which torching trees can be expected to ignite a spot fire. An extension of this model includes spot fire ignition distances from burning piles, jackpots, fuel concentrations, and surface fires (Albini 1981, 1983). Application of these models includes projecting spot fire distances for contingency planning, preattack activities, and large fire spread. A combined assessment of rate of spread, ignition probability, and spotting distance can aid the fire planner in estimating spread rates over and above the limitations of Rothermel's (1972) fire spread model.

Spotting distance prediction techniques.--Albini (1979) provides information on calculating spotting distances using nomographs. Basic input data includes tree species, number of torching trees, diameter of the torching tree, and tree height. Output is the maximum spotting distance in miles.

Chase's (1981) technique for calculating spot fire distance uses the TI-59 calculator. Magnetic cards store basic data and programs with input through the calculator keyboard. The input and output data are similar to that described by Albini (1979, 1981).

In addition, the BEHAVE computer program (Andrews, in preparation) has a spotting distance subprogram with input and output similar to that of nomographs and the TI-59 calculator.

National Fire-Danger Rating Components and Indices

Deeming and others (1977) developed the National Fire-Danger Rating System used by many wildland management agencies. Although the Components (spread, energy release, and ignition) do not directly predict fire behavior, they are useful in wilderness and park fire prescription development. The system also includes a burning index, which combines the spread and energy release components to estimate control difficulty, which is related to potential flame length and fireline intensity (Deeming and others 1977). Percentile levels of these components and indices have been used in many wilderness and park fire plans to establish prescription thresholds. The National Fire-Danger Rating System (Deeming and others 1977) is most applicable to monitoring seasonal trends and large area planning where site-specific data collecting exceeds logistical or economical constraints. Having a weather station that represents more than 1 million acres (404 694 ha) is the key to fire danger ratings because one representative weather station with an assigned fuel model can then provide long-term data to analyze an entire wilderness or park. Accessing historical weather data through computer programs allows (Main and others 1982) various output formats to define fire management prescriptions.

Calculation of fire danger components can be accomplished manually using graphs (Burgan and others 1977), a hand-held calculator (Burgan 1979), or computer programs that evaluate fire prescription criteria established for a given area.

THE ABSAROKA-BEARTOOTH WILDERNESS PLAN CASE EXAMPLE

In 1982, a wilderness fire management plan was approved for the Absaroka-Beartooth (A-B) Wilderness, in south-central Montana, to allow lightning-caused fires to more nearly play their natural role. The fire management plan used previously described planning techniques to assess potential fire behavior.

All Gallatin National Forest fire reports for fires occurring in the A-B Wilderness between 1974 and 1979 were matched with weather records at Mammoth, Wyo. Fuel moistures were adjusted for elevation using standard lapse rates for temperature and dew point. Wind, slope, and aspect data were taken directly from the fire reports. The TI-59 calculator was used to make fire spread projections for at least 2 days or until sufficient precipitation occurred to inhibit fire spread. Results of these projections are shown in table 1. Person-caused fires were included to increase the resolution of these projections. Acreages are overestimated in some cases because the fire spread model assumes continuous fuels, weather conditions, slope, and fuel moisture. Interpretation of these calculations suggests fires in the A-B Wilderness would be relatively small with a low potential for large stand replacement fires. Therefore, with low fire occurrence and small fire size, prescriptions were designed to be liberal within an acceptable risk to outside resources.

SUMMARY

Fire behavior prediction technology has advanced rapidly in the past 10 years. Potential applications of this technology to wilderness and parks fire planning are numerous. Many published documents and state-of-the-art tools provide the basics necessary for fire behavior planning. Only through a thorough understanding of the techniques and their applications can we begin to appreciate the long-term benefits of professional planning that gives the fire management field credibility in the eyes of the public and agency personnel.

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Fire name	Cause	Date of ignition	Projected size without suppression		Remarks and actual acres at suppression
			Acres	Hectares	
Bull Creek	Person	10/01/74	123	49.8	Late season fire, precipitation on 10/4/74. Sixty acres at suppression.
Tucker	Person	10/02/74	3	1.2	Late season fire, precipitation on 10/4/74. Spot at suppression.
Buffalo	Lightning	07/09/79	12	4.8	No precipitation until 7/22/79 (0.5 in). Spot at suppression.
Lake Abundance	Lightning	07/21/79	0	0	Sparse fuels, precipitation on 7/22/79. Spot at suppression.
Rock Creek	Lightning	07/21/79	2	0.8	Sparse fuels, precipitation on 7/22/79. Spot at suppression.
Pacos	Person	08/28/79	0	0	Precipitation on 8/28/79. Spot at suppression
Horse Creek	Person	09/18/79	25-50	10-20	Actually suppressed at 30 acres. Precipitation 7 days later.
Pine Creek Lake	Person	10/04/79	1-2	0.4-0.8	Sparse fuels. Two acres at suppression.
Wide Water Lake	Person	10/13/79	0	0	Precipitation on 10/15/79. Spot at suppression.

Total projected without suppression = 166 acres (67 ha)

Actual total with suppression = 92 acres (37 ha)

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ECOLOGICAL INFORMATION BASE FOR PARK AND WILDERNESS FIRE MANAGEMENT PLANNING

Thomas M. Bonnicksen

ABSTRACT: Quantitative and unambiguous standards of naturalness are essential for developing and evaluating park and wilderness fire management plans. Such quantitative standards of naturalness do not yet exist for any national park or wilderness area in the United States. The physical evidence needed to develop quantitative standards of naturalness is rapidly disappearing due to the effects of management fires, wildfires, decomposition, and successional changes. Therefore, a nationwide "rescue ecology" program is recommended to preserve as much remaining ecological information as possible.

INTRODUCTION

We are burning the past in our national parks and wilderness areas. The process thus far has been slow, but the pace of prescribed burning is quickening. With each new management fire more physical evidence from the past is lost, and with it goes another chance to learn about the structure and function of presettlement ecosystems. What is happening is similar to the way we lose knowledge about our human heritage when another archeological site is bulldozed, paved over, or flooded by a reservoir.

Once the physical evidence is destroyed, whether it is in the form of trees that grew in presettlement times or artifacts from a prehistoric culture, it is gone forever; it cannot be replaced. Of course, successional processes, even in the absence of fire, will eventually destroy the ecological record, just as geological processes will eventually destroy the archeological record. Management fires, however, can be controlled to minimize these losses. Although much of the physical evidence will be lost in any event, the information it contains and the knowledge it can produce will last forever; that is, if we record it. The problem is especially urgent because this knowledge is essential for park and wilderness fire management planning.

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THE NEED FOR STANDARDS

Dr. Stone and I analyzed the development of United States national park vegetation management policy in a previous paper (Bonnicksen and Stone 1982a), so here I would like only to reiterate our conclusion:

> The resource management goal of each national park is to preserve important natural features, as well as the "total natural environment or ecosystem." A natural ecosystem is defined as one that portrays, to the extent feasible, either the same scene that was observed by the first European visitor to the area or the scene that would have existed today, or at some time in the future, if European settlers had not interfered with natural processes.

In short, natural fluctuations and trends in the structure and function of national park ecosystems should be allowed to continue and, where necessary, be restored. This is a dynamic not a static definition of natural in which "scene" means structure and function on display. In fact, Dr. Stone and I demonstrated quantitatively that it is biologically infeasible to prevent the structure of a forest ecosystem from changing (Bonnicksen and Stone 1982a).

Restoration, however, implies a state or condition of an ecosystem and that, in turn, requires identifying when that condition existed or would have existed. Once an area is restored to its natural condition, natural changes would be allowed to continue; nature can take its course. Thus the scene being portrayed remains constant only in the sense that the sky remains a constant yet continuously changing kaleidoscope of clouds on a blue background.

Wilderness areas and national parks share a similar goal for managing ecosystems. Although the Wilderness Act of 1964 emphasizes visitor experience more than preservation, wilderness experiences depend upon natural conditions. In fact, the Act uses language that captures the essence of the definition of natural conditions when it states that wilderness should retain "its primeval character and influence" and that it should appear "to have been affected primarily by the forces of nature."

A park or wilderness ecosystem that has undergone major European settler-induced changes should be

restored to its natural condition before natural processes, such as fire, are allowed to operate freely. Natural fires are defined here as fires that behave in a manner that approximates fire behavior before the intervention of European settlers. Because variation in the vertical and horizontal arrangement of vegetation within an ecosystem influences fire behavior, natural fire behavior can only occur in natural vegetation. This conclusion is, of course, only a restatement of a fundamental principle of plant ecology; namely, that the functioning of an ecosystem is inseparable from its structure, and vice versa (Odum 1971).

Reinstating fire as a natural process requires deciding which specific natural condition will be used as a starting point. Will the ecosystem be restored to its presettlement condition, the condition that would have existed today if European settlers had not interfered with natural processes, or to the condition that would have existed at some specified future time? No matter which alternative is chosen, the resource manager must have a quantitative description of the target condition in order to judge the success of restoration. Such quantitative standards are lacking in all of our national parks and wilderness areas.

In the absence of such standards, resource managers have chosen to restore the process of fire in existing vegetation, whether it is natural or not. This is admittedly an interim goal, but as it is carried out, knowledge essential to achieving the ultimate goal of naturalness is lost. This is, however, an inevitable and justifiable cost that must be paid to achieve other goals. Resource managers cannot suspend prescribed burning while waiting for scientists to conduct research on the natural structure and function of ecosystems. In many areas, fuels are accumulating at an alarming rate and, as a result, there is an increase in the likelihood of catastrophic fires that would endanger human lives and developments and destroy even more physical evidence than prescribed fires. Thus, resource managers have wisely chosen to reduce fuels and forestall such losses.

The quantitative standards that can be used to evaluate the interim goal of fuel reduction are many and straightforward. They include containing prescribed fires, whether they are ignited by lightning, visitors, or managers, within predetermined boundaries. Scorch height can also be used as a quantitative standard along with a specified percentage reduction in heavy fuels. Using these and similar quantitative standards, resource managers can readily assess the success of their actions.

Clearly, most of the research on fire management has focused on refining the standards associated with fuel reduction and on the burning prescriptions that are most effective in achieving those reductions. Again, this research effort is justifiable given the interim goals that must be addressed. A problem arises, however, because fire is used to accomplish two goals simultaneously. The first, the interim goal of reducing fuel, is based on quantitative standards. The second and ultimate goal, to restore and maintain natural ecosystems, has no support from scientific research. The justification for not conducting the necessary scientific research is based on a hypothesis that contradicts the fundamental ecological principle pointed out earlier; namely, that reintroducing fire into an ecosystem with an unnatural structure will eventually produce an ecosystem in which both the structure and function are natural. If, however, structure and function are inseparable characteristics of an ecosystem, it logically follows that the natural structure of an ecosystem must be restored before fire will interact with that structure to produce a natural ecosystem. In fact, Bonnicksen and Stone (1981) reported empirical evidence supporting this conclusion. If this fundamental ecological principle is denied without supporting scientific evidence (which if proven correct would be revolutionary), the standard for judging success is faith, or worse, administrative fiat, not science. The standard is subjective, not objective, and it is certainly not quantifiable. The unique natural values within our national parks and monuments are finite, perishable, and irreplaceable. These resources belong to all of the people, both in present and future generations. There is no justification for using faith as a standard for judging the success of management practices when the cost for error is so enormous.

Using faith as a standard produces other associated consequences that are also undesirable. Perhaps the most important of these is a relaxation in efforts to secure the research funding needed to document the presettlement or natural structure and function of national park and wilderness ecosystems. Obviously, if managers are confident they are restoring natural conditions by simply reintroducing fire, there is little incentive to seek funds for developing quantitative standards of naturalness. Conveniently, resource managers also avoid being held accountable for their actions. Without quantitative standards, there is no objective way of judging success. The public is forced into the position of believing resource managers when they declare they have restored natural conditions, yet the managers themselves cannot know whether they are right or wrong.

There are three equally effective ways of justifying the lack of quantitative standards. One way is to declare that aboriginal people were not a natural part of the ecosystem and that as a result the effects of their fires were unnatural as well. This argument, of course, means that presettlement or natural conditions are redefined as those that existed before occupation by aboriginal peoples, which could involve many thousands of years. Clearly, no known methods exist for reconstructing preaboriginal ecosystems over so long a period, at least in any manner useful to management. Consequently, no quantitative standards are possible

and faith is given enhanced legitimacy as a subjective and untestable, but unavoidable, standard.

A second way of avoiding quantitative standards is to challenge the results of studies that attempt to reconstruct the presettlement structure and function of ecosystems. Of course, any responsible scientist wants to do the best job that knowledge and resources allow and therefore normally welcomes such criticism. When, however, such criticism leads toward the conclusion that it is impossible to achieve even a reasonable degree of accuracy in the reconstruction of presettlement conditions the result is inevitably a reliance on faith because no alternatives are thought to exist.

Finally, quantitative standards can be avoided by simply declaring that both aboriginal peoples and European settlers are natural parts of national park and wilderness ecosystems. This leads to the conclusion that anything that resource managers do is natural. Fortunately, I am unaware of any serious proposals that advocate this point of view.

Regardless of the reason for relying on faith, the result is delay in conducting essential research and the continuing loss of physical evidence that must be used to determine the presettlement structure and function of national park and wilderness ecosystems. Furthermore, successional processes and decomposition will do their work on the physical evidence even before management fires and wildfires have a chance to erase the ecological record. Time is short, and action is needed now before the only alternative left is a reliance on blind faith.

THE KINDS OF STANDARDS THAT ARE NEEDED

There are nearly as many ways to describe ecosystems as there are studies. This diversity of techniques is also present in the scientific literature on vegetation reconstruction. Such methods include verbal recollections, diaries, historical photographs, land survey records, pollen analysis, and the use of live and dead plant material. The last-named method involves reconstructing presettlement vegetation on a particular site and is the most direct, quantifiable, and accurate approach. Whatever method is chosen, the resultant description must be quantitative if it is to serve as a standard for judging the success of efforts to restore natural ecosystems in park and wilderness areas.

In addition to being quantitative, descriptions of presettlement or natural conditions should be unambiguous. For instance, conducting an inventory of trees and placing them in different age or diameter classes will provide quantitative data. If such data were available, a resource manager could readily compare the age or diameter class frequencies for current and presettlement conditions. Such data, however, are ambiguous and cannot be used as the primary standard for assessing the naturalness of vegetation. The same frequency distribution could be produced by completely different vegetation structures, even if the species composition is identical. A uniform arrangement of trees of different sizes or ages, such as in a plantation, could, for example, produce the same frequency distribution as a random arrangement of trees. The same result could also be produced by trees that grow in small, even-aged groups. Similar problems exist with such measures as biomass accumulation, basal area, net primary production, and ecosystem respiration. Ambiguous measures should be avoided as much as possible in developing dependable standards of naturalness.

The key ingredient needed in quantitative standards of naturalness is the arrangement in space of all the important elements of an ecosystem. As Potter and Kessell (1980) point out, "To produce information for the manager that can be utilized to weigh management alternatives, we need to supply not only numbers but also pictures." Displaying numbers in a form that represents their areal distribution provides such a picture. Therefore, ambiguity in statistical sampling results for quantitative standards of naturalness can be reduced by stratifying vegetation into homogeneous units. Ambiguity can still present a problem, however, if the criteria for determining homogeneity are inadequate.

Two choices are possible for using homogeneous units of vegetation to define relatively unambiguous standards of naturalness. First, vegetation can be stratified at the "composition-structure-phase," which is the lowest level in Brown's and others' (1980) hierarchical classification of ecosystems. This approach involves mapping units of vegetation as small as single aggregation types (Bonnicksen and Stone 1982b). In a forest, for example, a group of trees of similar size and age, with the same number of layers or tiers and composed of the same species, constitutes an aggregation. A group of pole-size white fir with no understory trees is an aggregation type, as is a group of mature sugar pine trees with an understory of sapling-size white fir. In both cases, composition and structure are the criteria for defining homogeneous units of vegetation. The resulting standards of naturalness consist of the size of aggregation types, the proportion of the landscape occupied by particular aggregation types, and the internal characteristics of each type, including such measures as density, basal area, fuel loading, and others. This high-resolution approach would probably be limited to those park and wilderness areas in which individual vegetation units, or aggregations, cover large areas. These standards of naturalness could also be applied in small areas, where the high values at risk are greater than the cost of management.

The second choice involves stratifying vegetation at the next-to-lowest level of Brown's and others' (1980) classification of ecosystems and sampling for structural attributes within these ecosystems. This level refers to plant associations based on

the occurrence of particular dominant species, and it is similar to the habitat type as defined by Daubenmire and Daubenmire (1968), Layser (1974), and Pfister and others (1977). The habitat type, however, is better suited to producing standards of naturalness because it generates more homogeneous ecosystems than the association. For instance, ponderosa pine *(Pinus ponderosa)* association could be further subdivided into the ponderosa pine/bluebunch wheatgrass *(Agropyron spicatum)* habitat type and the ponderosa pine/chokecherry *(Prunus virginiana)* habitat type, among others. Nevertheless, since the habitat type is based on the hypothesized climax vegetation for an area, it includes pockets of seral vegetation intermixed with patches of climax vegetation. This is the "fine-structure" that must be quantified to provide dependable standards of naturalness. In other words, what is needed is information on the proportion of the habitat type that would be covered by seral vegetation types and climax vegetation under natural conditions.

These structural groups of seral and climax vegetation within a habitat type are equivalent to aggregations, and they can be further classified into aggregation types that represent their successional status (Bonnicksen and Stone 1982b). Because these data could be readily and economically obtained from systematic point sampling within habitat types, this second approach can be used to provide dependable and quantitative standards of naturalness over extensive areas.

THE NEED FOR ACTION

The physical evidence necessary to restore the natural structure and function of park and wilderness ecosystems is rapidly diminishing. These losses are final, and the information that vanishes with this evidence is irretrievable. The seriousness of this problem does not stem from the total area that has already been burned by management fires, which as of 1981 amounted to only 5 percent of the area within natural fire management zones (Kilgore 1983). It is, instead, a result of where these management fires occur. We do not know, for example, how the scientific value of the physical evidence may vary from place to place within these zones. Consequently, we do not know if we are allowing management fires to burn the most valuable evidence before it can be salvaged.

I encountered a situation this past summer that drove home the potential seriousness of this problem. As part of a study I am conducting to determine the degree to which management fires are restoring presettlement or natural conditions in giant sequoia-mixed conifer forest ecosystems, I had to locate suitable postburn study areas along with unburned control areas. The study areas were in Giant Forest, Sequoia National Park, and in the Redwood Mountain Grove of Kings Canyon National Park, Calif. To my surprise, I was able to find only one unburned control area in the Redwood Mountain Grove, and that area was left unburned because the Park Service did not have the resources needed to conduct a planned prescribed burn. I encountered a similar problem in Giant Forest.

Management fires were concentrated in these two sequoia groves to protect them from wildfires, but the price paid for this protection was the loss of physical evidence needed to develop standards of naturalness for the groves. Tradeoffs such as this are routinely made by resource managers, and they are usually well thought out and justified by the known facts. It is what managers do not know, however, that is of primary concern here.

A PLAN FOR ACTION

Following World War II, the Interagency Archaeological Salvage Program was created within the Park Service to reduce the loss of archeological resources (Gramann 1979). This "salvage archaeology" program (now referred to as "conservation archaeology") was designed to identify and recover information from prehistoric sites before they were lost to reservoir impoundments, highway construction, and railroad relocations. Subsequent legislation has bolstered this program. A similar nationwide program of "rescue ecology" is urgently needed to forestall the loss of ecological information that is essential for park and wilderness fire management planning.

Such a program should begin by identifying regions within park and wilderness areas that do not differ significantly, in composition and structure, from what would have existed if European settlers had not interfered with natural processes. Areas that fail this test of naturalness should be subdivided to represent the chance that they will be burned by management fires in the near future or at a later time. Research efforts should then be concentrated, at least initially, in those areas that resource managers intend to burn.

Limited funding will probably necessitate using somewhat imprecise quantitative standards of naturalness to identify regions that are still in a near-natural condition. On the other hand, high-value areas that resource managers intend to burn should be studied intensively. In forest ecosystems, this means stratifying the vegetation into habitat types, or their equivalent, and conducting systematic point sampling for aggregation types. At each sample point, the current aggregation type should be recorded. Next, the number of trees, by species and size class, on the point should be projected backward in time from their current age to the year that represents presettlement conditions. Then, based on the age, size class, and species of the trees that would have been present at that time, the appropriate presettlement aggregation type should be recorded. Whenever possible, dead plant material should be used to help reconstruct the presettlement vegetation. Similarly, scientific evidence on the presence of shrubs and herbaceous plants should be used to complete the reconstruction.

This procedure will furnish data needed to determine the difference between the current proportion of each habitat type that is occupied by a particular aggregation type and the presettlement proportion occupied by that type. If presettlement vegetation is the target, or baseline, condition needed to reintroduce fire, then these data provide the necessary quantitative standards of naturalness. If the area passes the test of naturalness, burning can begin; if it does not pass, restoration can begin.

Further research will be needed, however, if resource managers wish to take advantage of the changes that would have occurred under natural processes from presettlement times until the present. Such research may be called for in situations where particular aggregation types are overrepresented or underrepresented relative to presettlement conditions. This is exactly the problem that resource managers face in giant sequoia-mixed conifer forest ecosystems. A much larger proportion of these ecosystems is represented in aggregations dominated by pole-size white fir than was the case under presettlement conditions (Bonnicksen and Stone 1982b).

Removing overrepresented aggregation types from an ecosystem can be accomplished mechanically. There is ample precedent for this approach in the national parks. Pole-size white fir, for example, were cut by resource managers in the Mariposa Grove within Yosemite National Park and in the Redwood Mountain Grove within Kings Canyon National Park. Such methods are expensive, however, so they will probably be reserved for small, high-value ecosystems.

The two most promising and least costly methods of restoring the composition and structure of ecosystems are limited mechanical manipulation coupled with prescribed burning and prescribed burning alone. Regardless of the approach used, restoration will involve selectively reducing fuels, creating conditions suitable for the regeneration of underrepresented aggregation types, and removing overrepresented aggregation types.

Resource managers could minimize the removal of overrepresented aggregation types by estimating how many of the individual aggregations within a type would have survived until now if natural processes such as fire had not been altered. Of course, those that would have survived would not be removed. Computer-based stand prognosis models can be used to make these estimates of the natural composition and structure of ecosystems. Presettlement vegetation is the baseline from which such projections are made because that was the last time that natural conditions existed. The projected present state then serves as the quantitative standard of naturalness for the ecosystem.

A "rescue ecology" program should, therefore, focus on four main goals. First, it should develop quantitative standards of naturalness for each habitat type found in United States national parks and wilderness areas. Second, it should identify regions within parks and wilderness areas that currently fit these quantitative standards of naturalness so they can be left alone. In those regions that do not meet the quantitative standards of naturalness, restoration efforts should, at least initially, be concentrated where management fires are planned. Third, prescribed fire research should be expanded to include the effects of fire on aggregations. Accelerated research to develop burning prescriptions for controlling the composition and structure of vegetation will make it possible to restore natural conditions over extensive areas at an acceptable cost. Once the natural composition and structure of an ecosystem are restored, fire will operate as a natural process.

The fourth and final goal of such a program should be to document the natural fire frequency within ecosystems and the source of ignitions. Kilgore and Taylor (1979) found, for instance, that Indian-caused fires substantially augmented lightning fires in Sierra mixed-conifer forests. Barrett and Arno (1982) reported similar findings for Northern Rocky Mountain forest types. They also found that fire intervals were shortest in Indian-use zones. This means that reintroducing fire and expecting it to operate as a natural process requires not only natural structure as the starting point but also requires natural or presettlement fire frequency. In some zones, lightning-caused ignitions may be adequate to maintain a natural fire frequency. In other zones, lightning fires may have to be augmented with prescribed fires that simulate Indian burning. Therefore, the "rescue ecology" program should include recording fire scar and other fire history data before it is lost. Achieving all four of these goals is necessary for park and wilderness fire management planning.

CONCLUSIONS

Park and wilderness fire management planning requires ecological information that describes the objectives to be achieved. These objectives must be quantitative and unambiguous. Because park and wilderness areas share a common goal of preserving natural conditions, these objectives must also be expressed as quantitative standards of naturalness. Natural conditions are defined here to be those that existed when an ecosystem was first observed by European settlers, or the condition that would have existed today or at some time in the future if European settlers had not interfered with natural processes. Quantitative standards of naturalness must also include information on the composition, structure, and areal arrangement of vegetation in order to be useful to fire management planning.

The physical evidence needed to develop quantitative standards of naturalness is rapidly disappearing because of the effects of management fires, wildfires, decomposition, and successional changes. Consequently, it is recommended that a nationwide "rescue ecology" program be initiated

to recover as much of the remaining ecological information as possible before it is gone forever. This evidence from the past is finite, perishable, and irreplaceable. The loss of this information would be tragic because standards of naturalness do not yet exist for any national park or wilderness area in the United States. Such quantitative and unambiguous standards of naturalness are absolutely essential for evaluating the success of park and wilderness fire management planning.

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EVOLUTION OF THE NATURAL FIRE MANAGEMENT PROGRAM AT SEQUOIA AND KINGS CANYON NATIONAL PARKS

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ABSTRACT: The Sequoia and Kings Canyon National Parks' natural fire management program is the oldest of its kind in the United States. Past fire suppression practices had produced an unnatural accumulation of fuel, increasing the risk of high-intensity fires. Subsequent research showed fire was important to many park ecosystems and that fire could be reintroduced without harm under prescribed conditions. Each Park must define the goals of its natural fire management program, monitor its effectiveness, and continuously reevaluate goals, objectives, and methods.

INTRODUCTION

Fire has played a major role in shaping ecosystems of North America (Pyne 1982). In many areas, the presence or absence of fire controls vegetation succession, wildlife habitat, and nutrient cycles, as well as regulating biotic productivity, diversity, and stability (Heinselman 1978). It is now recognized that if examples of natural ecosystems are to be preserved it will be necessary to perpetuate fire as a natural process (Parsons 1981a). Because of fire's importance in preserving wilderness ecosystems, natural fire management programs have expanded greatly in the past 15 years. For example, lightning-caused fires are now allowed to burn in portions of 34 National Park or Forest Service areas (Kilgore 1982). Prescribed burning[1] to reduce unnatural fuels so that lightning-caused fires can be allowed to burn is also used in some National Park Service natural areas.

To carry out any effective natural fire management program, it is first necessary to define the goals of the program. This might include protecting certain species, perpetuating a given scene or point in time or, as has evolved in recent years in National Park Service natural areas, perpetuating natural processes such as fire (McCool 1983).

For example, in Sequoia and Kings Canyon National Parks the goal of the natural fire management program is to preserve or restore fire as a natural process where it does not threaten human safety or property or to escape from these Parks. This goal is accomplished by permitting natural fires to burn in certain areas and by substituting prescribed burning where the effects of fire suppression must be reversed or mitigated before natural fires can be allowed to burn. The emphasis is on preserving or restoring the dynamic character of the Parks' ecosystems, not on restoring a historic scene.

Before the program's goals can be implemented, a variety of ecological information must be collected so managers can fully understand the role and impact of natural fire. This information should include fire history and behavior as well as the effects of varying fire frequencies and intensities on ecosystems. An important use of these data is to assess changes in the role and behavior of fire caused by fire suppression and to aid the manager in deciding whether prescribed burning will be needed.

To be fully effective, a natural fire management program must also include monitoring to evaluate its effectiveness in achieving the stated goals (ideal ends or effects) and objectives (specific conditions that can be met). Natural fire management programs are dynamic and continually need refinement. By default or direct action, managers continually affect ecosystems' integrity, virtually always on the basis of less than complete information. New data, thoughtfully analyzed, can warrant program changes. The purpose of this paper is to review the evolution of the natural fire management program at Sequoia and Kings Canyon National Parks and the types of ecological information needed to develop, implement, and refine it.

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[1]Editors' note: Please refer to the Foreword for comments on prescribed fire terminology.

PAST PRACTICES

Sequoia and Kings Canyon were the first national parks in the United States to institute a natural fire management program that included natural ignitions and prescribed burning (Kilgore and Briggs 1972). To implement this complex program, information on the historical and ecological role of fire in the Parks was required. Today, after 15 years and some 236 prescribed natural fires (22,062 acres [8 932 ha]) and 107 prescribed burns (23,277 acres [9 424 ha]), information still is being collected to fully evaluate and refine the program.

Vegetation in Sequoia and Kings Canyon National Parks ranges from chaparral and oak woodlands at the lower elevations, through ponderosa pine, giant sequoia and mixed conifer forests at the middle elevations, to subalpine forests and barren rock at the higher elevations (Vankat 1982). Each of these communities has evolved under a specific combination of fire frequencies, intensities, and patterns, called a "fire regime" (Heinselman 1978). For example, chaparral is thought to have evolved with short-return-interval, stand-replacement fires; sequoia-mixed conifer and ponderosa pine forests with frequent, low-intensity surface fires; and subalpine forests with infrequent, low-intensity surface fires (Kilgore 1981).

In recent presettlement times, lightning-fire frequency was augmented by Indian burning in certain areas. Indians are thought to have burned for various reasons, such as increasing growth of food-producing plants and browse for wildlife (Vankat 1977). It is difficult to distinguish the effects of Indian fires from those of lightning fires on park ecosystems, although burning by Indians probably was more important in influencing ecological patterns than in developing specific adaptations to fire.

Following the displacement of the Indians in the 1860's, European settlers began to have a significant impact on the area. Extensive livestock grazing was accompanied by burning to increase forage. This burning, like Indian burning, probably increased fire frequency. Much of the settler burning was of unnaturally high frequency and intensity (Muir 1877). Such destructive fires eventually led to an era of fire exclusion.

The establishment of Sequoia and General Grant National Parks in 1890 called for the suppression of all fires; however, even in those early days of fire exclusion, concern was expressed over the increase of combustible fuels in the sequoia forests. To reduce the fuel hazard, an area was burned in General Grant National Park in 1904 (Wells 1906), and this became the first "prescribed burn" in the national park system. After this, a policy of fire prevention and suppression was established and remained in effect for the next 60 years.

Fire suppression resulted in an unnatural accumulation of fuel, particularly in the sequoia and mixed conifer forests; this accumulation reached a point at which the forest was threatened by fires of higher intensity than those to which it was adapted (Kilgore 1971a). The removal of fire also increased the density of fire-tolerant species such as white fir. The fire regime appeared to be changing from low to high intensity and from short to long return.

Severe wildfires in the Sierra Nevada in 1955 and 1960 demonstrated the potential of these dangerous fuels. These fires influenced the Leopold Report (Leopold and others 1963), which describes the importance of fire and other natural processes to the preservation of natural communities. As a result, the National Park Service shifted in 1967 to a policy that allowed natural fires and prescribed burning as well as suppression of wildfires.

EVOLUTION OF THE NATURAL FIRE MANAGEMENT PROGRAM

Early Research

The initial fire research in Sequoia and Kings Canyon focused on the importance of fire to the regeneration of giant sequoias. Beginning in 1964, plots were burned and various fire effects documented (Harvey and others 1980). Although 99 percent of the seedlings died within 2 years, the sequoia seedling survival was highest in the hottest burned areas, where fuels were cut and piled. Because other disturbance factors also tend to create a mosaic of vegetation types or successional states, Harvey and others (1980) concluded:

> The implication of this pattern for management is that fire as a tool probably should not be applied evenly in a short period of time throughout a large area. Prescription fires should be applied in a patchy manner thus coming closest to re-establishing the primitive mixed conifer forest. The overall long term goal should be the establishment of conditions that would allow natural processes to operate uninterrupted in the ecosystem.

Patchiness is the result of local variations in fire intensity. Based on Muir's (1909) description of a forest fire during early settlement times, Bonnicksen (1975) suggested that fuels were variably distributed and that flame lengths were generally less than 2 feet (0.6 m). In pockets of heavier fuels, however, 100- to 200-year-old sequoias were killed. Such information provided valuable insight into the fire regime of sequoia-mixed conifer forests.

In the late 1960's research into the natural role of fire grew in scope. Kilgore (1971a, 1971b) conducted studies on the use and effects of prescribed burning in giant sequoia and red fir forests, using prescriptions adapted from Schimke and Green (1970) that produced low-intensity, controllable fires. These burns reduced dead and downed fuel, killed the understory, raised crown height, and initiated seed germination of conifers. They were also thought to approximate the effects of primeval natural fires. The former study developed into the prescribed burning program in the Parks' mixed conifer forests; the latter study paved the way for the creation of a "let burn" or natural fire management zone in the higher elevations (Kilgore and Briggs 1972).

In summary, the information that led to the initiation of both the natural fire management and prescribed burning programs included recognition that fire was important in maintaining many park ecosystems; certain ecosystems were adapted to such long fire cycles (more than 25-year return interval) or were so remote that fire suppression had not been important to them; and in many areas where suppression did result in increased fuels, fire could be reintroduced without harm under prescribed conditions that at least partially simulated natural fire.

Implementation

In 1968, nearly 75 percent of these Parks (basically the subalpine and alpine zones) was set aside as a "let burn" or natural fire management zone (Kilgore and Briggs 1972). The only support of this strategy was observations that fires in subalpine forests behaved as primeval fires were believed to have burned: of generally low intensity with occasional torching of individual trees, or groups of trees, and no general crown fires (Show and Kotok 1924; Kilgore 1971b; Weaver 1974). There appeared not to have been sufficient fuel buildup in the past 60 years to alter the natural fire regime.

Although subalpine stands of red fir and lodgepole pine can often be found growing in extensive stands of similar diameter, no attempt was made to determine if the subalpine forest fire regime of the Sierra Nevada is actually a "variable regime" type (Kilgore 1981), with both frequent, low-intensity fires and long-return, stand-replacing fires. Even if the area had such a regime, however, fire suppression would not have had a major impact on the potential role of fire. At worst, it may have delayed fire's catastrophic appearance in this century, as well as possibly increasing eventual fire size.

In contrast to the natural fire management program, the prescribed burning of sequoia-mixed conifer forests in the early 1970's was hampered by a lack of a clearly defined goal. Neither the natural forest structure and dynamics nor the magnitude of change due to fire suppression were fully understood. Moreover, the question remained whether the Leopold Report (Leopold and others 1963) intended that "natural" be defined as the ecosystem structure that was in place at the moment of arrival on the scene by Europeans or as the general fire regime under which the communities evolved. Is the goal to recreate the 19th century forest, a "vignette of primitive America," frozen in time or to create what "would have been here" if fire suppression had not interfered? Or is it to restore the general fire regime and let natural processes determine the forest structure, even though the result may differ from the structure at the time of discovery? Is the role of the American Indian in the historic fire regime to be mimicked?

Such questions have appeared (Bonnicksen and Stone 1982a) and should be resolved, at least on the park level, before a natural fire management program is initiated. The program's managers in the 1970's focused on objectives rather than the goal and specifically on fuel reduction and white fir understory removal; Briggs (1976) notes that prescriptions and firing techniques were developed to remove 70-100 percent of the dead and downed fuel. The early documentation of "patchiness" was overlooked; homogeneity became the standard. White fir saplings and poles, whether occurring as a second tier under the mature canopy or as a young, codominant stand in an opening, were to be uniformly removed.

Prescribed burns conducted in the early to mid-1970's attempted to meet these objectives. Monitoring was restricted to recording mortality and, occasionally, fuel loading. Prescribed burns were conducted in 30- to 50-acre (12 to 20-ha) blocks, using strip head fires and 15- to 20-person crews. Bonnicksen and Stone (1981) reemphasized to park managers that the presettlement mixed conifer forest was a network of small "aggregations," even-aged, codominant clumps of trees in an uneven-aged forest. The concept of even-aged "aggregation" is not new. Cooper (1961) noted for ponderosa pine:

> The mosaic pattern of the forest has developed under the influence of recurrent light fires. Each even-aged group springs up in an opening left by the death of a predecessor. (After remaining intact for 300 years or more, groups break up quite suddenly--often in less than 20 years.) The first fire that passes through consumes the dead trees, and leaves a good seedbed of ash and mineral soil, into which seed drifts from surrounding trees. Young ponderosa seedlings cannot withstand even a light surface fire, but in the newly seeded opening they are protected by the lack of dry pine needles to fuel such fires. Consequently the young stand escapes burning for the first few years. Eventually the saplings drop enough needles to support a light surface fire, which kills many smaller saplings but leaves most of the larger ones alive. As

> a group of trees grows toward maturity, new seedlings germinate beneath it. The volume of dry fuel dropped by the older trees, however, supports fires hot enough to eradicate the seedlings entirely. Fire and shade together prevent younger trees from developing; the even-aged character of the group is maintained throughout its life.

Parsons and DeBenedetti (1979) observed that fire is a process that not only consumes fuel but also creates gaps in the forest, which are colonized by young conifers or shrubs. Thus fire suppression not only resulted in the frequently mentioned thickets of white fir understory but also allowed old, diseased, weak, and dead trees to remain standing, blocking the formation of new gaps and, therefore, of new seedling aggregations.

The work of Bonnicksen and Stone (1982a) is significant because it describes the structure of a sequoia-mixed conifer forest as it now exists and as it probably looked in 1890; the effects of fire suppression can be quantified and forest growth models can be generated to show the impacts of management actions. This work has led Sequoia and Kings Canyon Parks to examine the policy implications of the natural fire management program. Bonnicksen and Stone (1982b) suggest that the goal should be to reconstruct the forest structure as it was in 1890 (a curious choice, as that date follows several decades of settler burning) and only then allow natural fire to burn. They maintain that the present forest is deficient (relative to 1890) in seedling and sapling aggregations; overabundant in pole-sized aggregations, which germinated in unnaturally high numbers at the close of the 19th century due to fire exclusion; and that the poles should be removed with burning or mechanical means to increase the proportion of seedlings and sapling aggregations to 1890 levels.

The origin of the much-maligned pole-sized white fir aggregation is in question. Since pole-sized aggregations are, by definition, top tier, they germinated in openings that appeared about 100 years ago (Bonnicksen and Stone 1982a). If these openings were caused by, for example, cutting or burning by loggers, the Bonnicksen and Stone data document an artifact. If the openings are naturally derived, then there is nothing "unnatural" about them; the seedling aggregations of 1890 have aged to pole-size trees today, although fire would have thinned the stand somewhat. If there is an overabundance of any aggregations, it is of very old or dead trees that fire would have brought down and turned into seedbeds, and the truly unnatural white fir poles are those occurring as a second tier. These, as Cooper (1961) noted, would have been vulnerable to fire.

Refinement

The early 1980's have seen a significant increase in the appreciation of what ecological information managers need to have and in what they can use as tools in a natural fire management program. Prescribed burning has become more a science than an art as predictive capabilities become more accurate. Rothermel's fire spread model (1972), Albini's nomograms (1976), and Deeming and others' (1977) fire danger rating system are useful tools for natural fire management. In the refinement phase, research enjoyed a new ascendancy; Kilgore and Taylor (1979) developed a fire history for a sequoia-mixed conifer forest, including not only frequency but fire size and intensity. They also expressed the importance of Indian fires in increasing the fire scar frequency. Expanded studies of this type are needed for other sequoia groves and other vegetation types.

Parsons (1978) examined fuel accumulation rates in giant sequoia and started fire research in the chaparral zone (Parsons 1981b; Rundel and Parsons 1979). The effects of natural fires were also documented by Greenlee and others (1979) and DeBenedetti and Parsons (1979). Data on fire characteristics, behavior, and effects began to be routinely collected on all prescribed burns. Firing techniques changed from strip headfires to spot ignitions, allowing fuel characteristics to determine intensity, and recognizing at last the importance of patchiness in Sierra mixed conifer forest dynamics. This information, along with refined management objectives and strategies and more precisely defined responsibilities, is now part of the Parks' fire management plan (Bancroft and Partin 1979, revised 1984).

The basic reasons for the use of fire, and the ecosystem characteristics it is supposed to recreate or maintain, are only now being clearly defined. The opinions of "naturalness" have ranged from emphasis on ecosystem structure (for example, the suggestion by Bonnicksen and Stone [1982b] to recreate the structure of the 1890 forest and then allowing natural processes to function) to an emphasis on ecosystem dynamics. These Parks selectively use the whole spectrum, allowing natural fire where possible and prescribed burning to restore an approximation of the natural fire regime. In areas where natural fire is incompatible with public safety or some other constraint, prescribed burning in lieu of natural fire will be conducted to mimic the effects of natural fire. In specific "showcase" areas, historic structure will be maintained by artificial means.

Prescribed fire can be used to create any pattern of forest structure and function the manager desires; however, until the goals and objectives are clearly defined, its use must be conservative. The initiation of the natural fire and prescribed burning programs in these Parks was not supported by an adequate definition of the goal. Since Park Service policy does not clearly define "natural," it is the responsibility of each park to define the goals of its natural fire management program. Thus, the program's refinement phase has involved natural fire management techniques, data collection, and redefinition of the goals and objectives of the programs.

THE FUTURE

The future of the natural fire management program in Sequoia and Kings Canyon National Parks will involve at least five important components:

1. Redefinition of the goal of the program and, in particular, definition of what is "natural."

2. Continuation of prescribed burning of hazardous fuels and the gradual inclusion of these burned areas into the natural fire management zone. Prescribed burning will be used in areas in which natural fire and public use are incompatible and will mimic natural fire as much as possible. Detailed objectives for specific burns will be required.

3. Intensive surveillance of natural fires and accurate predictions of their behavior. As more of the Parks are placed under a natural fire strategy, the chances for accidents to the public by free-burning fire increase.

4. Monitoring of the effectiveness of prescribed fires in achieving stated objectives. This will involve an ecological monitoring program of fire behavior and effects on fuels and vegetation.

5. Continuous reevaluation of objectives and methods.

The goal of the natural fire management program is to restore or maintain the natural fire regime; this does not imply that the composition of the forest as first viewed by Europeans or as occurred at any given point in time will be precisely recreated or perpetuated, except in a few "showcase" situations. The ecosystems are dynamic, ever changing communities. They are adapted to short-term fluctuations in climate and fire regime. A half-century of fire suppression probably has not had any lasting effect that is not within the range of perturbation previously experienced. The focus is on function, not structure; consequently, much of the data collection will focus on fuels data that can be put into predictive fire behavior models.

Data also need to be collected on fire history and the effects of natural fire in communities included in the natural fire management zone. Such data will be used to write prescribed burning prescriptions in similar vegetation types that have been influenced by fire suppression. Future data collection will emphasize primeval fire behavior, present fire behavior without prescribed burning and, if prescribed burning is needed, the influence of prescribed burning on future fire behavior. Computer simulation of historical fire patterns, intensities, and frequencies will be helpful in these studies. The effects of natural fires must be quantified to act as guides, not only for a prescribed burn designed to mimic natural fire but also to give the park manager an appreciation of the full range of predictable intensities in natural fires, some of which may be incompatible with public use. It is the responsibility of the park manager to recreate and maintain an ecosystem in which fire can function in as nearly natural a way as is possible without endangering human lives or property.

CONCLUSION

The most critical step of a natural fire management program is to define clearly the program's goals. Concurrently, an understanding of what is to be considered natural must be developed. This involves resolving the question of managing for ecosystem structure or dynamics, determining the importance of Indian fires, and characterizing the natural fire regime under which the ecosystem evolved. The third point is critical to safe operation of the program. High-intensity fire regimes increase the risk of costly escape fires such as the Ouzel fire in Rocky Mountain National Park and the Mack Lake fire in Michigan (Kilgore 1982). A natural fire management program is never "let burn." All fire allowed to burn must be prescribed and controlled, and an understanding of natural fire behavior will guide the formulation of adequate control measures.

Data collection in these Parks, therefore, emphasizes the documentation of fire's role in ecosystem dynamics. Although investigations into the primeval structure of the ecosystem will shed light on fire's natural role, the focus should not be on structure, which is the result of myriad ecosystem influences, of which fire is only one. If, however, a natural area is to be managed for the preservation of some natural process and ecosystem dynamics, care must be taken to ensure that the process still exists and can play its former role. Some parks, as Leopold (pers. comm) believes, "are too small in area to relegate to the forces of nature that shaped a continent." If the area that is now a park seldom received lightning strikes, having been burned by fires originating some distances away, it may never receive the fire its ecosystems need if management waits for a "natural" or unscheduled fire.

Although it is apparent that professional natural resources management requires the most complete and accurate scientific information available, that information may be available only in imperfect form. Nonetheless, management decisions must be made, for even to do nothing is a course of action. Given our limited and imperfect information about forest structure, fire regimes, the role of Indians, and reasons to believe that long-term climatic variance probably has induced community structure changes far greater than those induced anthropogenically in the past century, we feel minimum intervention is the wisest and the most conservative management strategy. Our program of maintaining and restoring the natural fire regime (with a few carefully defined exceptions) is part of a larger view of these Parks--an International Biosphere Reserve and a living laboratory of natural ecological processes.

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Section 5. Park and Wilderness Fire Management Planning and Operation

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CRITERIA FOR EVALUATING THE ECONOMIC EFFICIENCY OF FIRE MANAGEMENT PROGRAMS IN PARK AND WILDERNESS AREAS

Thomas J. Mills

ABSTRACT: The appropriate economic efficiency criterion for selecting fire management program options in park and wilderness areas is the minimization of fire program cost plus the fire-induced change in the value of resource outputs. This is the same criterion that applies in other areas. Initial attack, suppression, and fuel treatment costs are relatively higher and the detrimental net value change in resource outputs is relatively lower in wilderness areas than in commercial timber areas; this difference suggests that fire management expenditures for fire suppression and hazard reduction within the interior of wilderness areas should be lower, and perhaps substantially lower, than expenditures in similar areas managed primarily for commercial timber. If high loss potentials exist beyond park and wilderness boundaries, creating a buffer to avoid fire escapes from the interior to adjacent areas is probably economically justified. Any complete analysis, economic or otherwise, requires clarification of the "natural state" wilderness management objective.

INTRODUCTION

Wilderness and park areas contain many unique resources, which is why they were initially reserved for special management. The criterion for economic efficiency evaluations of fire management programs in these areas is not unique but is essentially the same criterion used to evaluate programs in areas managed primarily for other resources. This paper briefly reviews the economic efficiency criterion as it applies to fire management program analyses and identifies some of the implications of applying that criterion for these wilderness analyses.

Economic analysis contributes to the decision process in two basic ways. First, it analyzes economic efficiency by condensing all dollar-valued inputs and outputs across time into a single index of desirability, such as present net worth or a benefit/cost ratio. Second, it analyzes opportunity cost by estimating the foregone economic efficiency of achieving certain non-dollar-valued objectives. Although an economic efficiency analysis is an important first step, a subsequent opportunity cost analysis is always appropriate when making natural resource management decisions because numerous program consequences cannot be valued in dollars.

Although helpful, economic analysis never provides all of the information needed for decisionmaking. A decisionmaker must always weigh the results of the economic analysis with other program consequences that cannot be measured in dollar units, or perhaps even quantified at all. Possibly one of the greatest assets of economic analysis is that it forces managers to clearly articulate management objectives and desired options. Without a clear management objective, no analysis can rationally proceed.

ECONOMIC EFFICIENCY CRITERION

Criteria for determining the economic efficiency of the fire management program were discussed as along ago as 1916 by Headley (Gorte and Gorte 1979). The U.S. Department of Agriculture, Forest Service, first entertained the idea of an economic efficiency criterion for fire management program selections in the early 1930's (Pyne 1982), but the trend toward adopting an economic criterion ended in 1934 when the Forest Service turned to the physical, but easily implemented, "10 a.m. policy," which required that the fire be controlled by 10 a.m. of the day following its discovery. This change came about partly because the economic efficiency criterion could not be implemented at that time. It was not until 1978 that the Forest Service (1981) returned to economic efficiency criterion for its fire management policy.

The appropriate economic efficiency criterion for fire management programs enables managers to maximize present net worth or, conversely, to minimize the cost of the fire management program plus the fire-induced impacts on the net value of resource outputs. Present net worth is modified into cost plus net value change (C + NVC) because it is difficult to measure the effects fires would have if there were no fire management actions. C + NVC is the sum of the presuppression expenditures, resulting fire suppression costs, and the net value change in resource outputs. The net value change can be positive (detrimental) or negative (beneficial).

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The cost of the management action must be compared to the management-induced change in the value of the outcomes. It is not sufficient to simply compare the cost of one fire management action to the cost savings generated in another fire management action. For example, even if an increased expenditure on fuel treatments is offset by reductions in fire suppression costs, this is no evidence that either action is economically efficient. The cost of both actions must be compared to induced changes in the value of resource outputs.

The C + NVC criterion has been discussed at length by several authors, including Gorte and Gorte (1979), Mills and Bratten (1982), and Simard (1976). Until recently, though, it was not possible to adequately measure the C + NVC of fire program alternatives. In the absence of that analytical capability, researchers compared fire program costs and resource output change in time-series studies (for example, Winkworth and others 1981). Although the time-series studies possessed several methodological weaknesses, such as the inability to control for parameters other than year-to-year changes in the fire management program level, they still provided some insights into the behavior of fire management systems.

The FOCUS simulation model's (Bratten and others 1981) application to estimate the C + NVC of alternative initial attack programs on six National Forests (Schweitzer and others 1982) was one of the first successful attempts to avoid the methodological problems of a time series approach. The simulation capability described in the Fire Management Analysis and Planning Handbook (USDA Forest Service 1982a) was then used to estimate the C + NVC of initial attack program alternatives on 40 National Forests (USDA Forest Service 1980) and on several areas where fire management is provided by State agencies (USDA Forest Service 1982b). These studies are important steps in continuing efforts to apply the C + NVC criteria.

The fire system is inherently stochastic. The resulting variability in program performance should therefore be made clear to the decisionmaker, who can then evaluate risk consequences along with economic efficiency and other important criteria of each alternative. One way to display risk is by the probability distribution of C + NVC about its expected value (Blattenberger and others 1983). This proability information permits explicit representation of the trade-off between risk and economic efficiency in any fire program selection. The problem is that there is no operational probability model from which to draw these risk estimates; however, work is underway that will soon remedy this problem (Bratten 1982; Mills and Bratten 1982).

A simple comparison between fire management costs and dollar-valued net value changes in wilderness areas and commercial timber areas illustrates some of these points. Although not a complete simulation of program alternatives, the relative economic efficiencies are clear.

COST OF FIRE MANAGEMENT ACTIONS

Initial Attack and Suppression Costs

The cost of initial attack and suppression actions on fire is substantial. Although generally high, the costs of initial attack inputs vary, as do rates of fireline construction. The corresponding differentials in the per unit cost of line produced is important because some of those inputs are not used in wilderness areas, either because their use is inconsistent with the wilderness management objective or because of poor access. Initial attack arrival times also differ between areas because of access differences, and longer arrival times mean higher suppression costs.

Estimates of the cost of initial attack inputs in the Forest Service's Northern Region (Montana and northern Idaho) range from $360 per hour for a 20-person Category I crew to $42 per hour for a two-person project crew (table 1) Gonzalez-Caban and others 1983). These costs apply to deployment status on small fires and include all the components required to place the productive input on the fireline including pay, training, equipment, facilities, and overhead costs.

Initial attack fireline production rates for hand crews and engines in a closed timber and litter fuel model (fire behavior officer fuel model 8) (Albini 1976) vary from 2 chains per person per hour for hand crews to 15 chains for a three-person engine crew (Schmidt and Rinehart 1982). The production rate for medium dozers on 26-40 percent slopes is 88 chains per hour (Phillips and Barney 1983). The resulting cost of fireline produced on small fires varies from a low of less than $1 per chain for dozers to a high of over $20 for helitack teams.

Although the fixed cost of moving crews and equipment to and from individual fires must be incorporated into a more complete calculus, the general tendencies are clear. The inputs generally excluded from wilderness areas, and used sparingly in parks because of their site disturbance potential (dozers and engines), are the most cost-effective once they reach the fire site. Hand crews sometimes walk into wilderness areas, which makes travel costs higher and cost-effectiveness lower than in roaded areas. Helitack teams are used extensively in wilderness areas because of the lack of road access, and they are the least cost-effective inputs of those shown in table 1.

Table 1.--Estimated cost of suppression crews and fire productivity rates in the Northern Rocky Mountains (1981 dollars)

Suppression crew	Cost on small fires[1]	Production rate[2]	Cost-effectiveness	Mean first arrival[3] Lightning	Person
	Dollars/hour	Chains/hour	Dollars/chain	- - - Hours - - -	
Category I crew[4] (20)[5]	360	40	9.0	3.9	1.6
Project crew[4] (2)	42	4	10.5	3.9	1.6
Helitack team (2)	82	4	20.5	3.8	3.2
Smokejumper team (2)	47	4	11.8	4.7	3.6
Medium engine (3)	60	15	4.0	1.9	1.2
Medium dozer (2)	78	88	0.9	2.1	1.5

[1]Costs are for the Forest Service's Northern Region.

[2]Production rates for the closed timber with litter fuel model, fire behavior fuel model 8.

[3]Mean elapsed time between detection and first arrival of initial attack crews for the respective crews. Estimates are based on individual fire reports, from 1970-82, in the Forest Service's Northern Region.

[4]Productivity rates and arrival times for Category I crews and project crews are for "hand crews."

[5]The number in parentheses is the number of personnel in the respective crews.

Wilderness fires are generally more expensive to suppress because they are usually far from roads, which places major restraints on the fire management approaches and equipment that can be used, and lengthens crew arrival times. On the other hand, road access is usually better in areas managed for commercial timber production, and the initial attack bases are generally closer to fire locations; these factors lower fire management costs.

Fuel Treatment Costs

Data on fuel treatment costs show that costs within wilderness are higher than in commercial timber areas. Fuel treatments undertaken to reduce fire hazard within wilderness areas or to return the area to its natural state are restricted to prescribed burning. Mechanical treatments, such as dozer piling, are excluded, just as they are excluded from suppression actions. Although mechanical treatments are not always the most efficient treatment, they are no doubt more efficient in some circumstances. McKetta (1983) estimated the cost of 12 broadcast burns on the Lolo National Forest in 1982 at $554 per acre and the cost of 20 dozer pile fuel treatments at $133 per acre.

Even prescribed burning costs are higher in wilderness areas than in commercial timber areas under comparable treatment conditions, partially because the wilderness areas tend to be at the higher elevations. Bunnell (1983) estimated that broadcast burning costs $381 per acre on the Lolo National Forest for 10- to 20-acre summer burns, on aspects other than north and east under difficult mop-up conditions. The cost for the same type of treatment site at lower elevations was $75 per acre less. The cost of comparable prescribed burns is also more in wilderness areas because crews cannot use engines cost effectively, and it is more expensive to transport hand crews to the more remote wilderness fires.

Two factors, however, at least partially offset these tendencies for relatively higher fuel treatment costs in wilderness areas. In commercial timber areas, the high fuel loadings left from timber harvesting often require treatment, and the burn size is often small because the harvest blocks are small (Bunnell 1983). Both of these factors tend to increase the cost of prescribed burning in commercial timber areas. Jackson and others (1982) estimated the cost of 61 broadcast burnings undertaken primarily to improve wildlife habitat in the Forest Service's Northern Region in Fiscal Years 1979 and 1980. The average treatment cost was $18 per acre (1981 dollars). The costs of burning natural fuel accumulations within wilderness areas probably more closely correspond to the costs of wildlife burns than to costs of burning post timber harvest slash loadings, which are the basis of McKetta's and Bunnell's estimates.

NET VALUE CHANGE IN RESOURCE OUTPUTS

Fire-induced changes in resource value have typically been determined by a postfire damage appraisal calculation (for example, Marty and Barney 1981). Only recently have more generalized net value changes been available for use in program evaluation and planning exercises.

Net value change equals the present net worth of the future stream of resource outputs in the absence of fire on the site minus the present net worth of resource outputs in the presence of fire on the site. The "absence of fire" benchmark is just that: a benchmark needed for the net value change computation. It is not a normative statement that the absence of fire is good. Note that a net beneficial effect is represented as a negative net value change and a detrimental effect is a positive net value change, similar to the way "losses" might be treated.

The net value change estimate is affected by the management context within which the fire occurs, assumptions about substituting unburned resources for burned resources, and the completeness with which changes in the magnitude and timing of resource outputs are represented in the calculation. The absence of timber harvesting and rangeland grazing in wilderness areas is an example of management context considerations. If the trees were not going to be harvested in the absence of fire, no "timber" net value change exists.

Following the procedures described by Althaus and Mills (1982), net value change estimates have been calculated for fires typically encountered on public lands in the Northern Rocky Mountains. Resource value estimates and management regimes reflect those generally applied on Forest Service lands in the Northern Region.

Timber Net Value Change

Estimates of the timber net value change under intensive National Forest management in the Northern Rocky Mountains vary greatly and depend on characteristics of the fire and the fire site. Mills and Flowers (1983) applied a fairly complete timber net value change computation to a detailed set of cases involving high-site Douglas-fir, ponderosa pine, and fir-spruce. Their computations showed net value changes that ranged from $1,385 per acre (a net loss) to -$376 per acre (a net gain) (table 2). The net value change of seedling and sapling stands is generally low, and the net value loss is generally high in small fires with moderate mortality rates in poletimber and sawtimber stands. Net value gains come from large, high-mortality fires in poletimber and sawtimber stands, thus ending an uneconomic rotation and producing valuable salvage.

Table 2.--Estimates of timber net value change per acre burned in the Northern Rocky Mountains[1]

Cover type	Productivity class	Stand size	Tree mortality	Fire size	Net value change
	Ft^3/acre/year		Percent	Acres	Dollars/acre
Douglas-fir	120+	Sawtimber	30-59	100+	[2]-376
Douglas-fir	120+	Poletimber	60+	0-9	1,385
Douglas-fir	120+	Seedling/sapling	0-29	10-99	0
Ponderosa pine	85-119	Sawtimber	60+	0-9	661
Ponderosa pine	85-119	Poletimber	0-29	100+	498
Ponderosa pine	85-119	Seedling/sapling	60+	0-9	296
Fir-spruce	50-84	Sawtimber	60+	0-9	311
Fir-spruce	50-84	Poletimber	0-29	100+	311
Fir-spruce	50-84	Seedling/sapling	60+	10-99	266

[1]All cases assume the fire site is on slopes of greater than 40 percent and is in roaded areas.

[2]Negative net value changes reflect net beneficial effects, and the positive estimates reflect net losses.

Recreation Net Value Change

The net change in recreation value also varies as a function of fire intensity and recreation use level, but there are few estimates of fire-caused recreation net value change in the Northern Rockies. Estimating recreation net value changes produced by fire is also methodologically difficult (Vaux and others 1983). The only reasonably satisfactory method to date requires eliciting willingness-to-pay bids from campers and hikers, who are shown paired photographs of fire sites before fire and at different times after fire.

Flowers and others (1983) reported recreation net value changes in the Northern Rocky Mountains that range from $5 per acre burned for a high-intensity, sawtimber fire to less than $1 per acre burned for a light understory burn in a sawtimber stand (table 3). The bids drawn from campers and hikers were multiplied by the total number of recreation visitor days in all recreation categories except fishing.

Table 3.--Estimates of recreation net value changes per acre burned in the Northern Rocky Mountains

Fire intensity	Recreation use[1]	Net value change
	Visitor days/ year/acre	Dollars/acre
Light[2]	0.19	<1
Light	.41	<1
Light	.87	<1
Heavy[3]	.19	1
Heavy	.41	2
Heavy	.87	5

[1]The recreation use levels represent visitation in the Northern Region from 1979-81.

[2]The "light fire" was represented by photographs of an understory fire in a ponderosa pine sawtimber stand that killed shrubs but not trees.

[3]The "heavy fire" was represented by photographs of a fire in which all trees in a Douglas-fir sawtimber stand were killed.

Hunters and fishermen, however, may bid quite differently. McCool's willingness-to-pay study (1983) of hunters and fishermen tests this hypothesis. The recreation net value change estimates are so small compared to timber numbers, however, that such a methodological problem or population difference is unlikely to significantly affect the fire program conclusions drawn.

Tolerance of fire increases with knowledge of its effects. This increased tolerance may increase the acceptance of less aggressive fire suppression policies and the use of fire as a management tool (Zwolinski and others 1983), but it does not necessarily lead to a greater acceptance of recreational activity on the burned site by the recreationist (Taylor and Daniel 1982). If the knowledge of effects does not influence the recreational use level or willingness-to-pay bids, however, it does not affect the net value change estimate. Educational programs, therefore, may not influence the economic efficiency implications of fire on recreational usage.

Range Net Value Change

The range net value change estimates are also small in relation to the timber estimates. The sample of Peterson and Flower's (1983) range estimates shown in table 4 varies from $7 per acre (a net loss) for summer fires in mountain grasslands to -$21 per acre (a net gain) in poletimber stands of Douglas-fir, western larch, and western white pine.

Water Net Value Change

Illustrative estimates of water yield net value change are all net gains (table 5) (Dave Peterson, personal communication). They are also generally small. Related estimates of the net value change associated with sediment production are also in net detrimental and very small.

Structure Net Value Change

Structural loss from wildfire is the only dollar-valued net value change that approaches the timber net value change in magnitude. For example, Schweitzer and others (1982) reported simulated structural losses as high as $469 per acre burned in the San Bernardino National Forest in Southern California. Historical data on structural loss from wildfires is poor, however, and should be improved. There have been few structural losses due to wildfire in the Northern Rocky Mountains, but the potential exists for significant losses in selected areas. The proximity of those few areas to commercial timber, park, and wilderness areas may have an important impact on the economic efficiency of fire management actions.

Table 4.--Estimates of range net value change per acre burned in the Northern Rocky Mountains

Cover type	Stand size	Grazing utilization	Season of fire	Tree mortality	Net value change
		Percent		Percent	Dollars/acre
Douglas-fir, western larch, and western white pine	Poletimber	40		>70	-21
Lodgepole pine	Sawtimber	25		>70	-8
Ponderosa pine	Poletimber	40	Summer	60	-11
Ponderosa pine	Sawtimber	25	Summer	30	-2
Mountain grassland		40	Summer		7
Sagebrush		25	Spring		-11

Table 5.--Estimates of water yield net value change per acre burned in the Northern Rocky Mountains[1]

Stand size	Slope	Tree mortality	Fire size	Net value change
	Percent	Percent	Acres	Dollars/acre
Seedling & sapling	0-39	30-59	0-99	-2
Seedling & sapling	40-79	30-59	100-999	-3
Seedling & sapling	40-79	60+	0-99	-8
Sawtimber	0-39	30-59	0-99	-1
Sawtimber	40-79	30-59	100-999	-3
Sawtimber	40-79	60+	0-99	-4

[1]All estimates are for roaded Douglas-fir sites at elevations above 4,500 feet that are not managed for commercial timber yields.

Non-dollar-Valued Effects

Net value changes are not available for several fire effects because it is not possible or appropriate to assign dollar values to them. Fire impacts on threatened and endangered species, cultural resources, human life, air quality, and long-term soil productivity are examples of impacts not included in the net value change estimates previously discussed. Secondary impacts of fire disruptions on the surrounding community are also excluded (Marty and Barney 1981).

A special non-dollar-valued effect in wilderness and park areas is the fire program's role in moving the ecosystem closer to its "natural" state. For example, the National Park Service's policy is to use fire to perpetuate natural ecosystems (Kilgore 1983). The reasons behind this policy are not clear. One purpose may be to produce a particular set of ecosystem conditions, which may include animal habitat, a stable food supply, and specific hydrologic dynamics. Another may be to return an area to its natural state because of its subsequent usefulness in scientific research. An example of such research would concern whether Indian-caused fires are part of the natural state or whether they cause the same sort of disturbance as fires caused by humans in recent times. Both of these changes would be difficult to quantify.

"Natural" fire frequency has been measured by dating fire scars on trees and by studying age-class distributions of existing timber stands (for example, Arno 1980). These are all attempts to measure the frequency of fire occurrence and fire severity in a highly stochastic system. If the preservation intent is the real objective behind the natural state objective, this substantial natural variation would make it very difficult to determine when the objective is achieved.

NET VALUE CHANGE AND COST COMPARISON

The net value changes for the dollar-valued outputs from wilderness areas (recreation, water yield, and the expected estimates for sediment production) are all small and in net may be zero. The net value changes for the dollar-valued outputs in commercial timber areas (timber, range, and structures) are, on the other hand, considerably larger and in net detrimental. The cost of initial attack, suppression, and fuel treatment is higher in those areas (wilderness) where the net value change of resource outputs appears to be relatively small. That is, the cost of the management action is greater where the resource output payoff for the action is less.

Although this is far from a full economic efficiency analysis of program alternatives, these results are strong enough to permit us to draw conclusions about the relative costs of efficient fire management expenditures in wilderness and in commercial timber areas. The magnitude of economically efficient fire programs in commercial timber areas is larger, and perhaps considerably larger, than in wilderness areas. These estimates contain little economic efficiency justification for initial attack, suppression, or fuel treatment in the interior of most wilderness areas.

HOMOGENEITY AND BOUNDARY CONDITIONS

Wilderness areas and parks are not homogeneous, however. Some portions of these areas are used much more often than others for recreation. Increased use is often associated with structural additions such as campgrounds in wilderness portions of parks. The detrimental net value changes for recreation and for structures that occur after high-mortality fires may justify fire management in those high-use locations. Because the recreational net value changes is relatively low unless the recreation use level is extremely high, however, most of the economic efficiency justification is tied to potential structural losses. The greater accessibility of these high-use areas also makes fire management costs lower than in the interior of wilderness areas.

The variability in costs and net value change in boundary areas between parks or wildernesses and adjacent land managed for other outputs is similar to that found within the park or wilderness. Even if a wildfire causes no substantial net value change within the wilderness interior, its escape beyond the wilderness boundary could cause considerable loss. The high density of structural development sometimes found around parks provides the same potential for significant losses from escaped fires.

The efficiency implication of this transition in net value change at the boundary is that the fire management program within, but close to the boundary, should focus more on the potential net value change caused by an escaped fire at the boundary than on change caused by fire in the interior. Initial attack and suppression should be more aggressive near the boundary, and there is more justification for a fuel treatment program near the boundary to reduce the fire hazard (Kilgore 1983). This buffer strategy is included in the fire management plans of some National Parks.

This boundary condition is not unique to park and wilderness areas, just as the economic efficiency criterion is not unique in those special use areas. Bridges (1983), for example, analyzed a "green belt" buffer between the chaparral hills of San Bernardino National Forest and the city of San Bernardino in southern California. The primary economic justification for fire management in most southern California chaparral areas is reduced loss from fires that escape into highly developed surrounding areas, not the net value changes that are averted within the chaparral. A secondary justification is fewer off-site effects, such as flooding, from fires that burn exclusively within the chaparral.

Reductions in recreation and range effects within the chaparral area do not justify fire management in such areas. The same is true of many remote wilderness areas.

SUMMARY AND CONCLUSIONS

An appropriate economic efficiency criterion for park and wilderness areas is the minimization of the cost of fire management programs plus the fire-induced changes in the value of resource outputs (C + NVC). The relatively lower cost of initial attack, suppression, and fuel treatment and the relative higher detrimental net value change in commercial timber areas justify much higher fire management expenditures in these areas than in wilderness areas. Except in unusually high-use areas within the boundary of a park or wilderness area, there is almost no economic efficiency justification for initial attack, suppression, and fuel reduction expenditures within the interior of the area.

When the potential net value change in adjacent areas is great, however, a boundary condition exists that warrants special consideration. Expenditures for prescribed burning to create a buffer may be efficient, although further analysis is needed to demonstrate this conclusively.

A pressing need in park and wilderness management is clarification of the "natural state" concept. Producing a particular set of ecosystem conditions differs greatly from creating a natural area suitable for scientific research. Each objective could lead to very different management programs. No analysis, economic or otherwise, should proceed until the management objective is clear. Once the objective is clear, economic analysis can assist in the selection of efficient and effective fire management programs, especially in the estimation of the opportunity costs of achieving outcomes that are dominated by non-dollar-valued outputs.

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MANAGEMENT CONSIDERATIONS FOR A COST-EFFECTIVE FIRE MANAGEMENT PROGRAM IN NATIONAL FOREST WILDERNESS

Everett L. Towle

A satisfactory and valid approach to identifying and implementing an effective and efficient fire management program for National Forest lands has been long sought. The burns of 1910 and other early years created a social and political climate characterized by the position that fire in the woods was inherently unacceptable because of the costs and losses it generated. Early attempts to improve the economic picture by increasing protection expenditures in hopes of decreasing losses did not work out. Costs rose dramatically, reductions in dollar losses were hard to show, and major fires continued to occur with regularity. Consequently, fire program emphasis shifted to a uniform, Forest Service-wide policy of early control of <u>all</u> fires; the change was based on the not unreasonable premise that this policy would reduce burned acreage and minimize costs and wildfire losses in the long run. This approach was, in fact, effective in that reductions occurred in both numbers of fires and acres burned. Because the policy was implemented when a large force of CCC workers was available for fire programs, the policy did not immediately affect protection costs. When significant escalations in costs finally occurred, however, the efficiency of attacking and suppressing all wildfires on all areas was seriously questioned. From this questioning came a revised and more flexible fire policy for National Forest lands that permits local fire programs to be matched to local conditions.

National fire management policy requires fire protection and use programs to respond efficiently to land and resource management goals and objectives. This means implementing a fire protection and use program for each area that is appropriate from a standpoint of cost, the value of the resources and improvements protected, and the probability that these values will be affected by wildfire. To do this, we need to identify the fire program that minimizes total cost and net fire-induced changes in resource values. This is simply an update of the old "minimum cost plus loss" objective that recognizes the potential benefits as well as the negative consequences that can accrue from fire.

Implementing this policy requires defining with reasonable accuracy the kinds and amounts of resource outputs that are part of the planned management objectives for each area. It requires an associated ability to estimate the probable positive as well as negative effects fire would have over time on the quantity and quality of these outputs under a variety of fire size and behavior conditions. And finally, it requires the ability to apply some rational value system to these outputs that allows costs and benefits to be measured on similar scales.

Fire management programs in National Forest wilderness are guided by the same policies as programs for other National Forest System lands, except as they must be necessarily modified to conform to specific requirements of the Wilderness Act of 1964 or other management direction. Application of these policies in wilderness raises a number of challenging management considerations.

First, fire management direction for wilderness in land and resource planning tends to be goal oriented. That is, it is usually presented in terms such as "restore the role of fire" or "allow fire to play a more natural role." Actual objectives for the total management program in goal-oriented direction may be obscure and subject to considerable individual personal interpretation. We must be sure we clearly specify in tangible terms what we expect to accomplish. Specific program objectives and constraints must be defined for each wilderness. An example of a specific program objective would be to perpetuate a specific vegetative type or pattern that is desirable for wilderness. These must be site-specific when that is important. We must then plan and manage fire and fire protection for some particular purpose within those objectives and constraints.

Second, with few exceptions, on-site wilderness outputs and values are intangible. They are not marketplace products with economic dimensions. In wilderness, we are forced to deal more with quality than quantity. Identifying the dollar value returned for the dollar spent on fire (or for any other kind of management) is, for all practical purposes, difficult. At best, we often can do no more than identify the most effective program and the cost associated with achieving an objective. We then can decide whether the value of meeting that objective is more or less than that cost (called an "opportunity cost" in economic parlance) or whether there are better competing uses for those dollars.

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In considering economics, we also need to recognize that traditional tangible measurements of fire effects may run counter to wilderness management objectives. We need to be careful in selecting program planning, monitoring, and evaluation criteria. For example, one tangible measure employed to quantify wilderness outputs is the annual number of visitor days in an area. One consequence of wildfire can be a reduction in that annual number if a major burn detracts from the esthetics of the area. In such a case, the assessment of probable effects of wildfire in a particular wilderness might include assigning tangible economic damages based on the value of lost user days. Given these potential economic consequences, we could be led to plan an efficient and effective fire protection program based on mitigating these fire impacts. If such a burn should occur, however, it could well be exactly what the doctor ordered for the primary management objective of maintaining a natural diversity of flora and fauna through the periodic reinitiation of the natural fire succession cycle. Our planned protection action based on apparent economic efficiency would thus be counterproductive in the long run.

For an efficient and effective fire program to be planned in such a situation, we must use care to define and respond to the right objectives. We must also know the specific outputs or values that are being protected and their priorities: wilderness experience for users now or the dynamics of the wilderness itself over the long term.

The policy for planning suppression action on all National Forest System lands requires every wildfire to receive a prompt, appropriate response. What is appropriate for each area and situation is based on an economic efficiency criterion of meeting management objectives, given current and expected burning conditions, with minimum suppression cost and resource loss. Depending upon the circumstances, the response may range from a suppression objective of immediate control at the smallest practical acreage burned to one of fire confinement within a broad area, principally through natural barriers or conditions. The variables in the response selected are the amount and kind (and thus cost) of the suppression force.

Applying this policy to wilderness provides considerable opportunity to develop and implement a protection program that meets the area's management needs and objectives in an effective and efficient way. Particular management constraints in some areas may require special (and more costly) considerations with respect to suppression equipment and tactics in order to preserve wilderness values. On the other hand, management objectives may recognize a role for fire in the overall management scheme. In that case, fire consequences would be considered neutral, if not positive, in a given area. Here, a less aggressive (and less costly) suppression response becomes appropriate to meet an objective of confinement within the planned area. In both instances the suppression action planned and taken is that which most efficiently responds to both fire protection and resource management constraints and objectives.

An important aspect of this policy is the possible conflict that may come from attempting to respond simultaneously to positive fire objectives within the wilderness and to less fire-tolerant ones outside its boundaries. This is an especially significant problem in smaller wilderness units and in areas where past protection practices have allowed the buildup of hazardous fuelbeds. In these areas, wildfire starting in the wilderness can be quickly carried outside to affect resource or improvement values there. Obviously, carefully assessing the situation and evaluating the probabilities and consequences of the wildfire escaping the planned area of confinement are essential. We need to be as certain as possible, given an acceptable level of risk, that the strategy selected is in fact the least costly in the long run.

I have dwelled principally on the protection aspects of wilderness fire management. The role of prescribed fire must also be considered in developing an efficient program in those areas where historic protection may have too effectively removed wildfire from the wilderness environment creating unnatural fuel conditions and, concurrently, in those areas where wildfire would be damaging to values within or adjacent to the wilderness. In such areas, however, we first need to be certain that fire protection, and not a period of low fire impact in the natural wildfire cycle, has been the culprit. We must also be certain that fuel reduction through prescribed fire would be in harmony with the management objectives and prescriptions for that wilderness. Consider from a fire protection standpoint, the objective of prescribed fire use is to mitigate unnatural hazardous conditions. Once that is done, natural conditions should be perpetuated through a fire protection program geared to the area's management objectives, as I have discussed previously.

In summary, the planning of the fire program for National Forest wilderness requires clearly identifying the management objectives for each wilderness area and the potential for fire to support or disrupt meeting those objectives in that area. In wilderness, as in other resource areas, we must have specific, measurable expected outputs and not just broad goals. Given these, an efficient, effective fire management program can be developed that is responsive to land and resource management needs both within and adjacent to the wilderness.

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James K. Agee

ABSTRACT: Evaluations of fire management programs have been based primarily on ecological criteria rather than on cost-effectiveness. Determining cost-effectiveness poses several problems: current budgeting practices do not encourage such evaluations, assessment of the net value changes produced by fire is qualitative, and cost-effectiveness of fire management alternatives is difficult to determine. This discussion focuses on two approaches to determining cost-effectiveness. The first, a survey of cost-effectiveness in parks with complex fire management plans, showed most managers had considered cost in developing their programs but lacked data to demonstrate cost-effectiveness. The second, a simulation model based on the Olympic National Park fire management program, suggests that measuring cost-effectiveness of complex fire management requires knowing costs of other fire management alternatives. If progress in complex fire management depends on determining and quantifying cost-effectiveness, it will be necessary to quantify the trade-offs associated with prescribed fires and wildfires.

INTRODUCTION

Because cost-effectiveness has rarely been a primary reason for introducing prescribed fire[1] into national park ecosystems, evaluating the cost-effectiveness of fire management programs has been a low priority. Most evaluations have concentrated on ecological rather than economic success. Economic analysis would be difficult even if cost-effectiveness had been a higher priority in the past because experience with complex fire programs is limited, the value of resource benefit or loss to ecosystems has not been quantified, and the current budgetary process makes it difficult to optimize fire management expenditures.

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"Cost-effectiveness" is defined as achieving a cost-related objective. It is not necessarily a cost optimization procedure but rather a means by which actual costs can be compared to projected costs. Within the National Park Service, an agency in which the total number of economists can be counted several times on one hand, this definition is the basis for a discussion of cost-effective fire management.

Several basic accounting problems surface when developing models to evaluate the cost-effectiveness of fire management. First is the budgetary process. Prescribed fire programs have generally been funded from park base funds, whereas fire suppression expenditures come from a regional base fund. If, for example, a park increases the amount of scheduled ignition prescribed burning and thus decreases wildfire costs, the park bears the cost of the prescribed burning and the regional account receives the benefits of reduced wildfire costs. From a park perspective, then, it could be argued that the most cost-effective approach is to eliminate all prescribed fire, thereby minimizing the cost to the park. Measured wildfire suppression costs, since they are paid from a different "pot," can thus be ignored by the park. In fact, parks must base prescribed fire programs on ecological rather than economic rationales because they cannot benefit economically from the prescribed fire portion of the program.

The second problem in developing a cost-effective model is the net value change produced by fire in the ecosystem. At "natural" intensities and occurrence rates, even high-intensity fires may have positive net value effects on the park if they perpetuate wilderness character. Quantifying this value is not feasible, however, because much of the increased value depends on the evaluator's perceptions about this uniquely American concept of wilderness.

[1]Editors' note: Please refer to the Foreword for comments on prescribed fire terminology.

The third problem of cost-effective model development is comparing alternatives. In evaluating a strategy, it is difficult to produce "with" and "without" effects of a management decision. Certain promising approaches like decision analysis (Seaver and others 1983; Radloff and Yancik 1983) suggest ways to evaluate strategies, but uncertainties in predicting probabilities and costs, especially when four or five levels of decisionmaking are involved, make it extremely difficult to predict values of alternative strategies.

Two approaches were used to evaluate whether National Park Service fire programs are cost-effective and what management factors most significantly affect cost. In the first, those parks with significant fire programs were polled about the type of program they had, its costs, and its cost-effectiveness. In the second, planning scenarios were analyzed using an existing fire simulation model for Olympic National Park.

THE COST-EFFECTIVENESS SURVEY

Survey Design

The cost-effectiveness survey was designed to draw on the National Park Service's 15-year experience in complex fire management. The survey sampled only those areas with significant fire management programs, arbitrarily defined as those with more than 1,000 acres (≅405 ha) burned by prescribed fire (scheduled or unscheduled ignitions). Of the 34 areas listed by Sellers (1982) and Kilgore (1983) as having prescribed fire programs, only 15 met the "significant" 1,000-acre (≅405-ha) burn definition. Experience with prescribed fire is at most a brief 15 years; less than 4 percent of park areas has been burned by scheduled or unscheduled ignitions even in parks with significant programs. In summary, the cost-effectiveness survey has sampled few areas with relatively limited fire experience. Of the 15 surveys mailed, 12 were returned in time to be included in this analysis.

Survey Results

The survey posed 10 questions about cost considerations in planning and implementing fire management. The responses are summarized in six different functional categories because several of the questions were closely related to others.

Question 1.--Was cost a significant issue in developing the complex fire management plan and, if so, in what way?

Cost was considered significant in two-thirds of the parks sampled. However, the larger programs generally indicated that initial justifications for prescribed fire were ecological rather than economic. Several responses indicated that increased costs for scheduled ignitions at the park level were anticipated and had occurred; the expectation was that wildfire costs would eventually diminish as a result of such up-front expenditures. Three parks responded that costs had significantly changed independently of plan implementation: two responded that budget cuts reduced presuppression and detection funds, and one responded that such expenditures had increased even though the wildfire problem had not.

Question 2.--Are naturally occurring ignitions allowed to burn in your park and, if so, what efforts were made to minimize the unanticipated costs of such fires?

The answers to this question were fairly uniform among parks that allow some natural ignitions to burn. Natural firebreaks (for example, cliffs, water bodies) were identified in the planning process as good containment boundaries for natural fire zones. Reasonable buffer areas were established where definite natural firebreaks were absent. Selecting remote areas for natural fire zones was common. Some parks used scheduled ignitions to protect isolated structures and built some fire lines with hand tools when natural barriers were absent or ineffective. Interagency coordination, particularly when such zones were adjacent to national forest or wilderness areas, has been effective in reducing fire suppression needs at the boundary of areas managed for similar values.

Question 3.--Has the use of scheduled or unscheduled prescribed fire been within the range of the economic cost or benefit initially anticipated?

Several parks did not respond to this question, as cost was not a significant issue in plan development and had not been adequately evaluated. Most parks that responded suggested the program was too young to evaluate or no mechanism existed to objectively evaluate the program. Most believed costs were roughly in the anticipated range. One park had a prescribed natural fire reclassified as a wildfire, resulting in significant expenditures and plan suspension. At least two areas have reclassified human-caused wildfires as prescribed fires if the wildfire achieves resource objectives for which a later scheduled ignition would be prescribed. This policy has saved suppression and programmed funds.

Question 4.--What are the unit costs of scheduled and unscheduled ignition and wildfire suppression?

Most parks responded with per-acre estimates of costs for each category. Unscheduled prescribed fire ranged from $0.50 to $12 per acre; scheduled prescribed fires ranged from $1 to $61 per acre; and wildfires ranged from $13 to $2,113 per acre. For western parks, the averages were $7, $19, and $1,830, respectively, over the past decade.

Question 5.--Has the planned use of fire decreased the area burned and/or costs associated with wildfires?

Opinion was divided on this question. With a complex fire management plan, many fires once automatically classed as wildfires are now allowed to burn. Although one might expect a substantial reduction in the area burned by wildfire when some wildfires are reclassified as management fires and a substantial cost saving because of reduced need to suppress fires, only 25 percent of respondents believed they could demonstrate that the areas burned by wildfire had decreased since the reclassification. Most, however, believed that the wildfire area will eventually decrease as fuel becomes less plentiful or as unscheduled natural fire zones become more widespread.

Opinion was similarly divided on costs. Two parks believed wildfire costs had declined as a result of the current plan, because of extensive scheduled ignitions. Five parks stated that wildfire costs had not declined; two of these had extra wildfire costs, and one park had suppressed several natural ignitions that were initially allowed to burn after detection. On the other hand, this park noted that several natural ignitions were allowed to burn that would have been expensive to suppress under the old plan. In general, suppression costs for management fires are much easier to document than are the savings generated by not suppressing certain fires.

Question 6.--On balance, do you believe the total cost of fire management has increased or decreased since implementation of a complex fire management plan?

Easily identified costs increased in nearly half of the parks because of the costs of escaped, prescribed fires; delays in initial attack caused by decisionmaking problems; costs of scheduled ignition; lack of incentive to save wildfire suppression funds (or conversely, the ease of access to a nonprogramed account); and difficulty in documenting savings on unscheduled planned ignitions that once would have been suppressed. One park believed costs to be about the same. Another believed costs were probably less since plan implementation, and two others said costs were less because of undesired reductions in programed funds. Three parks felt they could not respond given the current information base.

Survey Discussion

The survey results indicate that few generalizations can be made about the cost-effectiveness of complex fire management plans. The greatest agreement was about the types of planning and implementation that seemed to be cost effective for unscheduled ignitions. Nevertheless, the application of these planning procedures has produced mixed results. In some parks, most or all natural ignitions have burned without interference. In others, limited suppression has been necessary and has sometimes cost more than immediate suppression after detection. In one park, a major fire run out of a planned zone caused major additional suppression costs.

Forest fire smoke does not appear to have significantly increased costs for any of the programs surveyed. Those that mentioned smoke noted that they obtained burning permits as necessary or, being at high elevations, were exempted from permit and other requirements by state air resource agencies.

None of the parks surveyed were able to compare quantitatively the costs of the current plan with costs of the total suppression plan. Several noted they had little incentive to make a total fire program cost-effective because of park fiscal responsibility for prescribed fire and regional/national fiscal responsibility for wildfire. Cost-effective prescribed fire at the park level benefits only regional/national accounts. When cost-effectiveness becomes a major goal of total fire programs in the National Park Service, institutional changes in fire management organizations (for example, Lee 1977) and stricter accounting of fire management alternatives and strategies will be required.

THE COST-EFFECTIVE FIRE MODEL

Model Design

Some sort of model is necessary to evaluate cost-effectiveness of fire management alternatives, because two or more alternatives cannot be simultaneously implemented in a planning area and "expected" or long-run average results may require many years of application. Olympic National Park was chosen as a theoretical case study to evaluate cost-effectiveness of several strategies, even though it is a moist park with a long fire cycle, low fire incidence, and a total fire suppression policy until 1983. It offers, however, much of the information necessary to produce model output: a preliminary complex fire management plan (U.S. Department of the Interior, Olympic National Park 1983) and a fire cycle simulation model that produces fire size characteristics with and without suppression (Agee and Flewelling 1983). The value of the cost-effectiveness model is more qualitative than quantitative, although numbers are used to provide specific outputs.

The preliminary fire plan for the interior portion of Olympic National Park designates three management zones: a prescribed natural fire (p.n.f.) fire zone, in which most natural ignitions are allowed to burn; a conditional zone, in which lightning fires may or may not be suppressed depending on location, threat to values-at-risk, and the potential to spread into the exclusion zone; and an exclusion zone, where all fires are suppressed (fig. 1). All human-caused wildfires are also suppressed in all zones. This plan is subject to further change before adoption. The prescribed natural fire zone comprises 46 percent; the conditional zone, 22 percent; and the exclusion zone, 32 percent of the interior park areas. Lightning fire occurrence has almost exactly the same distribution over the period 1916-75.

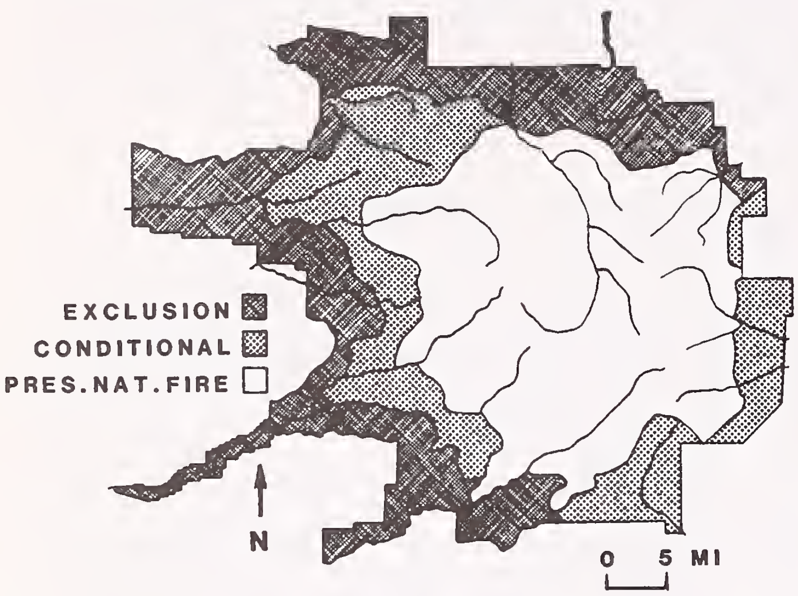

Figure 1.--Fire management zones for the preliminary fire management plan at Olympic National Park.

The fire model predicts a natural fire cycle of 3,505 years using historical weather data. With fire suppression built into the model, the fire cycle increases to 7,190 years, or 77 percent of the 1916-81 record. Seasonal distribution is predicted closely.

The fire model and preliminary fire plan were integrated with cost estimates for various activities to demonstrate the costs of alternative fire strategies. Several assumptions were made: (1) presuppression and detection costs remain constant for all alternatives; (2) delayed suppression action on a prescribed natural fire has no impact on fire size in this very rough terrain (this is consistent with the past several project fires in the park); (3) suppression costs of human-caused fires remain constant for all alternatives.

Costs were estimated in several ways. Suppression costs were conservatively estimated as $1,500/ac ($3,700/ha) based on the park survey for western parks. Monitoring costs for prescribed fire were estimated by area from the park survey ($6.75/acre; $16.67/ha) and multiplied by average annual area burned by prescribed fire. A second estimation was derived by multiplying the predicted fires per year by estimated cost per day by predicted length of fire; this calculation produced similar results. Only fires exceeding 2.5 acres (1 ha) were monitored.

The cost comparison did not include any cost category assumed to be constant in all alternatives. For the Olympic Plan, comparison was based on total average annual suppression costs of natural ignitions in the exclusion zone, any suppression costs in the conditional or prescribed natural fire zone, and any monitoring costs.

Four scenarios were developed to encompass a likely range of alternatives:

1. Continue suppression of all natural ignitions in all zones.

2. Suppress all natural fires in exclusion and conditional zones; allow all natural ignitions to burn in prescribed natural fire zone; no suppression action ever needed. Monitor all prescribed natural fires exceeding 2.5 acres (1 ha).

3. Scenario 2, except that natural ignitions are allowed to burn in the conditional zone; subsequent suppression action needed in varying percentages of such fires.

4. Scenario 3, except that suppression action is needed on varying percentages of fires in both the conditional and prescribed natural fire zones.

Model Results

The results (table 1) suggest that several complex fire management scenarios are more cost-effective than full fire suppression and that several other scenarios are less effective. The assumed trouble-free prescribed natural fire zone in scenario 2, which specifies suppression elsewhere, is roughly half the cost of the full suppression scenario. Even less expensive is scenario 3, as long as less than 40 percent of the conditional fires need suppression. If, however, suppression action is needed for more than 50 percent of conditional zone fires, it is cheaper to suppress all conditional zone fires upon detection (scenario 2), rather than allowing them to grow before suppression action is taken. Scenario 4, which specifies that varying proportions of fires in the conditional and prescribed natural fire zones need suppression action, is probably most realistic. Unless suppression is needed on more than 50 percent of such fires, however, scenario 4 is more cost-effective than full suppression.

Table 1.--Average annual costs of variable cost categories under four fire management scenarios at Olympic National Park

Scenarios and options		Suppression cost: Exclusion zone	Suppression cost: Conditional zone	Suppression cost: Natural zone	Monitoring cost	Total cost
	Percent	Dollars				
1. Full suppression		52,100	35,800	74,900	0	162,800
2. Prescribed natural fires only in p.n.f. zone		52,100	35,800	0	700	88,600
3. Prescribed natural fires in p.n.f. and conditional zones. Conditional zone fires needing suppression:	0	52,100	0	0	1,000	53,100
	10	52,100	7,400	0	1,000	60,500
	25	52,100	16,650	0	1,000	69,750
	50	52,100	37,000	0	1,000	90,100
	75	52,100	54,300	0	1,000	107,400
	100	52,100	72,400	0	1,000	125,500
4. Prescribed natural fire zone and conditional zone fires allowed; some of both need suppression action:	0	52,100	0	0	1,000	53,100
	10	52,100	7,400	15,000	1,000	75,500
	25	52,100	16,650	39,250	1,000	109,000
	50	52,100	37,000	74,900	1,000	165,000
	75	52,100	54,300	113,600	1,000	221,000
	100	52,100	72,400	151,500	1,000	277,000

Model Discussion

Two important implications are evident from this simple analysis. First, good planning for zone boundaries is very important. If frequent suppression actions are required, a complex fire management plan can be much more expensive than a total fire suppression plan. This simply reconfirms the cost-effective logic of the old fire adage, "Hit them while they're small." Second, even though limited suppression expenditures on "escape" fires appear to be high, they may be justifiable if compared to the costs of a full suppression plan. In this example, close to $100,000 per year could be spent to contain natural ignitions in either conditional or prescribed natural zones before total costs exceeded those of a full fire suppression scenario.

At least one major cost-effective consideration was omitted from this analysis; its inclusion could change the relative rating of results. It was assumed that fires would be suppressed with maximum effort and relatively high cost. If the suppression effort were less than maximum in some or all situations, costs per unit area would decrease. This is most likely to occur in the most remote areas and would be reflected most significantly in the prescribed natural fire zone suppression costs.

DISCUSSION

The test of cost-effectiveness is whether a desired cost goal is met: this goal can be one of minimum cost or one that recognizes stable or even increased costs are necessary to achieve certain resource objectives. Because most parks have not defined specific cost objectives, no conclusions can be drawn about the overall cost-effectiveness of complex fire management plans in the National Park Service. Cost comparison of other alternatives is lacking, and influences outside of the National Park fire plan (such as budget cuts) may affect actual costs of operation.

Planning stands out as a critical element of cost-effective fire management. Good fire planning will produce intelligent fire zone boundaries and will minimize those instances when subsequent fire suppression expenditures become necessary. In the extremely rugged terrain specified in the Olympic model, a complex fire plan can encompass a fairly high proportion of escape fires and still be more cost-effective than a full suppression plan. In other parks, the proportion of escape fires to be tolerated may be smaller; nevertheless, such a plan may still be cost-effective if total costs remain below those of a total fire suppression plan.

Scheduled ignitions are also used in wilderness fire management in the National Park Service. Costs of such ignitions vary widely because of differences in terrain, fuel conditions, tightness of the prescription, size of the area to be burned, and experience of the crew. Although such ignitions may reduce subsequent wildfire occurrence in the area, most ignitions have been used to help restore natural conditions in parks and appear to have increased overall fire management costs in the short run. Some of the factors associated with low-cost scheduled ignition are large size of burn (which spreads fixed costs over more areas); experienced crews (efficient firing techniques, nonexcessive staffing); and "loose" prescriptions (allowing on-site adjustments of firing patterns or area burned as long as the same objective is met).

Overall cost-effectiveness at the institutional level will have to integrate the costs of wildfires and prescribed fires. As an institution, the National Park Service has responded well to resource justifications for prescribed fire; however, it has been slower to respond to the organizational and budget allocation issues associated with complex fire management. If progress in complex fire management depends on determining and quantifying cost-effectiveness, however, it will be necessary to quantify the trade-off associated with prescribed fires and wildfires.

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ECONOMIC ANALYSIS FOR WILDERNESS FIRE MANAGEMENT: A CASE STUDY 1/

Michael K. Condon

ABSTRACT: The economic model used to evaluate fire management programs depends on the impacts produced by that program. This paper includes two case studies. In the first, the costs of fire management are compared to costs of fire suppression; in the second, fire management program costs are compared to net value changes. The manager must be aware of when it is appropriate to use these techniques.

INTRODUCTION

Fire management activities in wilderness areas have economic as well as ecological effects. The economic effects are program costs (suppression, presuppression, or prescribed burning costs) and net value changes. Net value change refers to changes in the market value of outputs resulting from physical changes in resources due to wildfire or prescribed fire. The objective of this paper is to show how to estimate the economic impacts of alternative fire management strategies in wilderness areas.

Cost plus net value change is the most commonly used criterion of economic efficiency for fire management programs (Althaus and Mills 1982; Gorte and Gorte 1979). Although not specifically designed for analysis of wilderness fire management activities, this criterion is applicable.

An economic analysis of a fire management program involves two primary steps. First, the format of the analysis must be identified. This requires defining alternatives and identifying cost components and affected resources associated with each alternative. In many cases fixed costs, such as an existing helitack module or lookout, would not change under alternative fire management programs. In this event, these costs do no need to be included in the analysis, even though the module in question might be part of the fire management program for the wilderness area. If, however, a change in fire management strategy involves dropping or adding a module, that cost difference needs to be included in the analysis. Once the program alternatives are defined and the appropriate components of cost and resource value change are identified, the valuation phase begins. In practice, the second step is the more difficult one. Data are often inaccurate or unavailable, which necessitates frequent use of assumptions. The need to make assumptions should not be intimidating, however, because reasonable assumptions can produce reasonably accurate results.

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The following two case studies provide examples of economic analyses for wilderness fire management programs. The format of each analysis is slightly different. The valuation phase in each case draws from several different data bases and employs several different quantitative methods.

THE ECONOMIC ANALYSIS OF THE PARK-CARIBOU UNIT OF THE LASSEN FIRE MANAGEMENT AREA

The Park-Caribou Unit encompasses 120,000 acres (48 563 ha) at the southern tip of the Cascade Mountain Range in northeastern California. Included are Lassen Volcanic National Park and the Caribou Wilderness, which is administered by Lassen National Forest. Although results could reasonably be projected over the entire area, this analysis deals only with the 20,000 acre (8 094 ha) Caribou Wilderness portion of the fire management area.

This analysis examines the economic implications of a prescribed fire plan using unplanned ignitions.[1] Changes in fire management strategy are not likely to have significant economic impacts on any on-site or off-site resource outputs. Accordingly, this analysis deals only with costs, rather than the "cost plus net value change" that is usually used to analyze the economic impacts of fire management programs. The cost of the traditional suppression strategy is included for comparative purposes.

Cost of Suppression Strategy

The cost of the suppression strategy is obtained by examining the fire records for 1977 through 1981 (table 1). Cost information on the fire records is

Table 1.--Suppression expenditures in the Caribou Wilderness Area (1981 dollars)

Year	Number of fires	Dollars spent on suppression	Inflation[1] factor	Suppression costs in 1981 dollars
1977	5	3,865	1.39	5,372
1978	1	200	1.29	258
1979	5	2,600	1.19	3,094
1980	0	0	1.09	0
1981	0	0	1.00	0
Total	11			8,724
			Average cost	793

[1]Calculated quarterly by the U.S. Department of Commerce.

[1]Editors' note: Please refer to the Foreword for comments on prescribed fire terminology.

not always complete, so it may be helpful to reconstruct and cost out a typical fire response to verify the reliability of the data. (All dollar figures throughout this analysis have been adjusted to 1981 dollars using implicit price deflators for gross national product [GNP] published by the Department of Commerce, Bureau of Economic Analysis.) Only 5 years' worth of cost data were used to develop an average yearly cost. Going back too many years many introduce some bias if typical suppression responses have changed over the years, for example, by increasing reliance on helitack crews.

Fire records since 1939 indicate an average of 1.4 fires per year. If the average cost per fire is $793 and the average occurrence is 1.4 fires per year, then the average annual suppression expenditure is $1,110.

Cost of Fire Management Strategy

No records are available to document the cost of implementing the Park-Caribou Plan; as they are to document the suppression alternative. It is possible, however, to make a reasonable estimate by breaking the cost into its component parts and using some known information along with some reasonable estimates to reconstruct the cost.

In a typical year a certain number of ignitions result in unplanned prescribed fires and a certain number result in wildfires. By estimating the number and cost for each type of fire, the average annual cost of implementing the plan can be estimated. The cost of implementation can be represented by:

$$C = N_m [(M \times D) + S_e] + (N_w \times S_w)$$

where:

C = Estimated average annual cost of plan implementation
N_m = Expected annual number of unscheduled prescribed fires
N_w = Expected annual number of wildfires
M = Cost/day for monitoring
D = Number of days of monitoring per fire
S_e = Expected cost for suppressing an escaped fire
S_w = Cost for initial attack suppression action

The first half of the right-side term is simply the number of management fires multiplied by the average cost of dealing with those fires. That average cost includes an allowance for dealing with escaped fires. Although an escaped fire is technically a wildfire, it is useful to make a distinction here because escaped fires are likely to be more costly to deal with than other wildfires that are suppressed quickly after being discovered. The second half of the term is the number of ignitions that result in wildfires multiplied by the cost of suppressing those fires.

Consider these variables one at a time:

N_m, the expected annual number of unplanned prescribed fires per year, can be estimated by multiplying the annual lightning fire occurrence (1.4 fires) by the percentage of fires that are expected to be declared prescribed fires. In this case, it was assumed that 80 percent of the lightning ignitions would result in prescribed fires. If 1.4 fires per year are multiplied by an 80 percent probability of a prescribed fire, the resulting value of N_m is 1.12.

N_w, the expected number of wildfires per year, is estimated by multiplying the number of fires per year (1.4) times the probability of a wildfire (1.00 - 0.80 = 0.20). If 1.4 fires per year are multiplied by 0.20, the resulting value of N_w is 0.28.

M, the cost per day of monitoring a management fire, is estimated by averaging the estimated costs of two levels of response to a monitoring situation. The first is a "light" monitoring situation and the other a "heavy," or more expensive, situation. These cost estimates are given below:

A. Light monitoring response (which could be by air or ground so both costs are developed)

1. By aerial reconnaissance from Chester; 1/2 hour flight time

$52.50	Flight time
6.00	Salary
$58.50	Total

2. On foot; two GS-5's for 1 day and 60 miles driven in pickup to trailhead

$100.64	Salary
12.60	Mileage
$113.24	Total

3. Cost of average light monitoring response = ($58.50 + $113.24)/2 = $85.87

B. Heavy monitoring response

Four-person crew (GS-5's) for 8 hours plus per diem expenses and 1/2 hour helicopter flight time

$200	Wages
85	Flight time
80	Per diem
$365	Cost of heavy monitoring response

C. Average monitoring cost = (heavy cost + light cost)/2

M = $(364 + 86)/2
M = $225

D, the average annual number of monitoring days, was estimated with a probability encoding technique. (A simple explanation of this technique is given by Staël von Holstein 1977.) Several people with fire suppression experience in the Caribou Wilderness Area were asked a series of questions about eventual fire size and the number of days light monitoring would be required. The following probability distribution was based upon those responses.

Number of days of monitoring	x	Probability of event	=	Expected value
1		0.57		0.57
5		.23		1.15
10		.13		1.13
15		.06		.90
20		.02		.40
		Average number of days per fire	=	4.15

S_e is the expected cost of taking a suppression action, either all-out or limited, on a fire that initially was a management fire. In this case it is assumed that 5 percent of all management fires will require some suppression action. A typical suppression actions is expected to cost $2,500. The expected cost per management fire equals the probability of a suppression action multiplied by the cost ($2,500 x 0.05 = $125). Therefore, S_e = $125.

S_w, the cost of an initial attack suppression action, is $7,983 (table 1).

Substituting the appropriate values in the formula for the cost of implementing a fire management strategy we find that:

C = 1.12 [($225 x 4.15) + $125] + (0.28 x $793)
  = $1,186 + $222
  = $1,408.

Long-range Projections

The amount and cost of monitoring unscheduled prescribed fires used in this analysis are probably excessive. The high costs used here are more representative of the first 5 or possibly even 10 years after plan implementation. Monitoring is most costly at first because of the need to gather information on fire behavior and effect so that the prescription and procedures can be versified or refined. As the plan is refined, both the agencies and the public become more comfortable with the plan and the need for data gathering decreases. As this happens, the cost of monitoring fires decreases. By comparison, if total fire suppression were to continue, costs would probably increase as flammable fuels continued to accumulate. Figure 1 demonstrates the changes over time of fire control versus fire management.

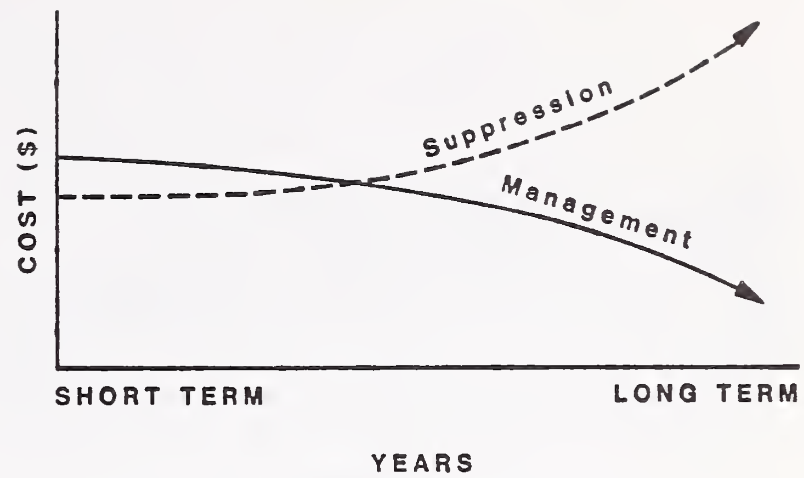

Figure 1.--Cost of fire management versus suppression.

Figure 1 demonstrates the long-run economic advantage of the prescribed fire alternative, but is based on costs only. If net value changes for nonmarket resources would somehow be considered, there could be additional advantage to fire management. To the extent that management fires contributed to ecological health and wilderness integrity, thus increasing the "value" of the resource, the fire management line would shift downward. The scars left by fire suppression tend to detract from wilderness values. These negative value changes would shift the fire suppression line upward.

Depending upon the size of these shifts, it is possible that even the short-run economic advantage would favor implementing the fire management plan. This would be true if wilderness integrity for the planning area is worth at least $298/year. This $298 is the difference between the average annual cost of the prescribed fire alternative and the suppression alternative. In this case, the graph would look like figure 2.

The situation depicted in this graph shows that there is an economic advantage (both long range and short range) in favor of implementing a fire management plan. This advantage is based upon many assumptions that were dealt with previously in this analysis. The graph shows a small advantage in the short run. (This short-run advantage occurs only if we accept that intangible wilderness integrity is somehow worth more than $298/year). The graph also shows that the economic advantage of a fire management policy will increase significantly over time.

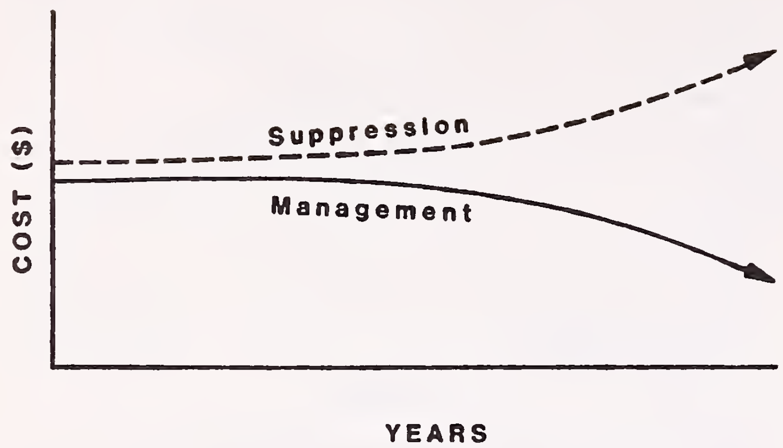

Figure 2.--Cost plus net value change of fire management versus suppression.

ECONOMIC EFFECTS OF TWO ALTERNATIVE FIRE MANAGEMENT STRATEGIES FOR THE PROPOSED ISHI RARE II AREA

The objective of this analysis is to compare the economic effects of two alternative fire management strategies for the Ishi Rare II area, which is located in the foothills east of the Sacramento Valley in Northern California. Vegetation is primarily oak woodland and chaparral with scattered stands of conifers.

The first alternative, which has been in effect for several decades, is characterized by aggressive fire suppression. The second alternative involves the use of prescribed fire from planned and unplanned ignitions. The objective of using prescribed fire is to promote wilderness integrity by allowing fire to resume its natural role in the ecosystem. This analysis compares fire management program costs to net value changes.

Unlike the Park-Caribou Unit of the Lassen Fire Management Plan, the alternatives considered for the Ishi Unit have significant effects on economic values in the fire management area. Although the concept of economic goods produced in a wilderness area might seem contradictory, such goods are, in fact, a reality that the land manager must be prepared to deal with. Water is probably the most common economic commodity that is potentially affected by fire management activities in a wilderness area. Impacts on the quantity and quality of water flowing from a wilderness area are likely to affect downstream uses such as hydroelectric production, agriculture, fisheries, and domestic consumption.

The Suppression Alternative

Costs for the suppression alternative are calculated by multiplying the per-acre costs for fire suppression by the number of acres burned per year. Costs for the fire suppression in the planning area are $692 per acre. This costs is based on actual suppression costs from fires in the planning area from 1971 through 1981. Costs were adjusted to 1982 dollars using GNP price deflators, which are calculated quarterly by the U.S. Department of Commerce.

A reasonable fire return interval is difficult to estimate for a fire suppression regime. The only certainty is that fire cannot be excluded indefinitely in a chaparral ecosystem. Since fire protection began, the average fire return interval has been slightly less than 20 years, but projecting the acres burned during the past 10 years, the interval appears to be nearly 850 years. This extremely long interval is due in part to a larger and more technologically sophisticated fire organization; more significant, however, is the fact that nearly the entire area has burned over since the 1920's. The vegetation over much of the area is just now approaching an age when flammability increases significantly, thus the low annual acreage burned during the 1970's is not likely to continue for long. This analysis assumes a fire return interval of 100 years. With 43,100 acres (17 442 ha) in the RARE II area and a fire return interval of 100 years, the expected annual acreage burned by wildfire is 431 acres (174 ha) (43,100 acres + 100 years).

The next step is to evaluate net value change. This is done with the aid of yield tables developed during the land management planning process.

Range benefits.--Range benefits are in the form of increased AUM's (Animal Use Months). The value of an AUM is $14. There is no loss of range resource in the year the fire occurs, because this area is winter range that the cattle have left by the beginning of fire season. Table 2 shows the increase in AUM's per decade and the value per year of the increase.

Table 2.--Increase in animal use months (AUM's) following fire in the Ishi RARE II area

Decade after fire	Annual increase in AUM's	Value of annual increase in AUM's
		- - Dollars - -
1	0.80	11.20
2	.62	8.68
3	.00	0.00

Because these resource value changes occur at different times, it is necessary to perform present value computations to account for the difference in timing. The present value concept is based on the

notion that a dollar today is worth more than a dollar at some point in the future. The following formulas are used to calculate present value:

Present value of a single payment:

$$V_o = \frac{V_n}{(1 + i)^n}$$

Present value of a periodic series of equal payments:

$$V_o = \frac{a[(1 + i)^n - 1]}{i\,(1 + i)^n}$$

where:

i = interest rate
V_o = present value in the beginning of year 1
V_n = dollar amount in year n
n = number of interest periods (years)
a = series of equal values.

The interest rate, i, is 4 percent as specified by Forest Service Policy (FSH 1909.17). The dollar value of the increased yield each year is $11.20 in the first decade. The number of years, n, is 10. Using the formula for the present value of a periodic series of equal payments, the present value in year 1 of the increase in AUM's during the first decade after the fire can now be solved:

$$V_o = \frac{11.20\,[(1+ 0.04)^{10} - 1]}{0.04\,(1 + 0.04)^{10}}$$

$$= \frac{5.378}{0.0592}$$

$$= \$90.83$$

An additional step is necessary in the case of benefits realized during the second decade after the fire. The present value computation calculates the value at the beginning of year 1, which in the case of the second decade is the first year of the second decade, or 11 years after the fire. Using the second decade value of $8.68 (table 2) in the periodic series, the formula yields a present value of $70.41 at the beginning of the second decade. This single value at the beginning of year 11 can be discounted to the present using the single payment formula:

$$V_o = \frac{\$70.41}{(1 + 0.04)^{10}}$$

$$= \$47.56$$

The total net value change in the range resource over two decades is $90.84 + $47.56 = $138.40.

Wildlife resource benefits.--Benefits to the wildlife resource are measured in changes in WFUD's (Wildlife and Fish User Days). The three kinds of WFUD's used in this analysis and their dollar values are:

WFUD	RPA dollar value
Big game	24.78
Upland game	32.01
Nongame	34.22

Resource Planning Act (RPA) values are from a memo from the Chief's Office (Hilmon 1981). Table 3 shows the increase in WFUD's and the corresponding dollar values.

Water yield benefits.--Increased water yields are estimated using the following equation which was developed to quantify changes in postburn water yields in the Sierra-Nevada foothills (Turner 1982).

$$Q = (6.69 \times \Delta P) - 12.97 \text{ inches}$$

where:

Q = quantity of water runoff in inches
P = mean annual precipitation in inches (30 inches this case).

Solving for Q yields 9.8 inches or 0.82 acre-feet of water per acre treated.

Unlike range and wildlife benefits, factors are available to calculate the annual distribution of the increased water yields. Most of this increase occurs in the first year following burning. The increase drops off rapidly until the 8th year when water yields have returned to preburn levels. Water used for agricultural purposes in California's Central Valley has a value of $31 per acre-foot (Sieg 1982). Existing storage and transportation facilities can handle additional runoff. Table 4 shows the present value of the increased water yield following a fire.

Table 3.--Average annual increases in WFUD's after a fire

Decade	Big game		Upland game		Nongame		Total annual value charge
	WFUD's	Value	WFUD's	Value	WFUD's	Value	
		Dollars		Dollars		Dollars	- Dollars -
1	0.078	1.95	0.024	0.78	0.080	2.73	5.46
2	.063	1.56	.019	.62	.040	1.37	3.55
3	.031	.78	.010	.31	.032	1.09	2.18

Table 4.--Present value of increased water yield in Ishi Rare II Area

Year	Annual distribution of increased yield	Cumulative yield	Value of an acre foot of water	Present[1] Value factor	Present value of increased water
		- Acre feet -	- Dollars -		- - Dollars - -
1	0.599	0.82	31	0.962	14.65
2	.451	.82	31	.925	20.60
3	.342	.82	31	.889	7.73
4	.252	.82	31	.855	5.48
5	.174	.82	31	.822	3.69
6	.104	.82	31	.790	2.09
7	.041	.82	31	.760	.79
8	.000	.82	31	.731	.00

[1]Derived from the present value equation and available from most any finance textbook (see Christy and Roden 1973).

Next present value of the changes in productivity of the fish and wildlife resource can be calculated in the same manner as for the range resource using the annual value change figures from table 3 and the present value formulas. The results of these calculations follow:

Decade	Annual value change	Present value of value change for decade
	- Dollars -	- - Dollars - -
1	5.46	44.29
2	3.55	18.70
3	2.18	11.48
	Total present value	74.47

Combined net value change.--With the net present value change calculated for each of the three resources (water, range, and wildlife), the total net value change can be calculated by adding the values for the three resources.

	Dollars/acre
Water	35.98
Range	138.40
Wildlife	67.54
Combined net value change	241.92

The cost plus net value change model was originally referred to as the cost plus loss model. The "net value change" replaced the "loss" portion of the model in recognition of the fact the fire can have positive as well as negative effects. The positive effects, or benefits, can offset at least some of the losses resulting from wildfires, but as it is applied in the model, the net value change is still really a measure of net damage. The net value change in the Ishi RARE II case is a measure of positive effects or benefits and therefore must be assigned a minus sign before it is applied in the model, because benefits are really the same as negative damages. (If you are intrigued by this sort of strange logic, economics literature is full of it.)

Cost plus net value change; suppression alternative. --All of the information is now available for the final identification of cost plus net value change. Adding the net value change of -$242 to the fire suppression cost of $692 yields a cost plus net value change of $450/acre ($182/ha). Multiplied by the excepted annual burned acreage of 431 acres (174 ha), the total cost plus net value change is $194,812 per year.

The Prescribed Fire Alternative

This alternative involves the use of prescribed fire to maintain the wilderness character of the area. Prescribed fire will result from planned as well as unplanned ignitions. Approximating the natural fire return interval of 35 years, which was estimated using fire scar analysis, requires prescribed burning of 1,231 acres (498 ha) per year (43,100 acres ÷ 35 years). In addition to this, probability encoding is used to estimate that 25 acres (10 ha) per year will be burned by wildfire.

Costs

Costs for prescribed fire from planned ignitions in and around the planning area have ranged from $25 to $75/acre ($10 to $30/ha). No data are available for prescribed fire from unplanned ignitions, but the costs can be expected to be higher than for planned ignitions. This analysis assures an average cost of $100/acre ($40/ha) for all prescribed burning. Costs for this alternative are summarized in table 5.

Table 5.--Costs for prescribed fire alternative in Ishi RARE II area

	Cost per Acre	Cost per (Hectare)	Burned per year Acres	Burned per year (Hectares)	Cost per year
	- - Dollars - -				Dollars
Prescribed fire	100	(40)	1,231	(498)	123,100
Wildfire	692	(280)	25	(10)	17,300
Total			1,256	(508)	140,400

Net Value Change

The net value changes per acre calculated for the previous alternative are still applicable for this alternative. The only difference is in the number of acres burned (1,231 acres [498 ha] by prescribed fire and 25 acres [10 ha] by wildfire for a total of 1,256 acres [508 ha]). Net value change for this alternative is summarized in table 6.

Table 6.--Net value change: prescribed fire alternative

Resource	Net value changes per Acre	(Hectare)	Number of Acres	(Hectares)	Total net value change
	- - Dollars - -				- Dollars -
Range	138	(56)	1,256	(508)	173,328
Wildlife	68	(27)	1,256	(508)	85,408
Water	36	(15)	1,256	(508)	45,216
Combined	242	(98)			303,952

Cost Plus Net Value Change

A final determination of cost plus net value change can now be made using values from tables 5 and 6. See table 7.

Table 7.--Cost plus net value change: prescribed fire alternative

	Per Acre[1]	(Ha)	Burned per year Acres	(Ha)	Planning area
	- Dollars -				Dollars
Cost	112	(45)	1,256	(508)	-140,400
Net value change	-242		1,256	(508)	-303,952
Cost plus net value	-130	(-53)			-163,552

[1]This price per acre cost was calculated by dividing the total cost for prescribed fire and wildfire from table 5 by the number of acres burned annually.

Conclusions--Prescribed Fire Alternative

The suppression alternative has an estimated cost plus net value change of $194,812. The prescribed fire alternative has a C + NVC of -$163,552. The negative C + NVC indicates that this fire management strategy produces more specific benefits than costs.

Many assumptions have been used in this analysis. Some are more easily substantiated than others. Reasonable changes in the more questionable assumptions would not change the economic advantage of the prescribed fire alternative, only the magnitude of the advantage. For example, if the cost of prescribed burning is doubled from $100 to $200/acre ($40 to $80/ha) the C + NVC is still -$40,452. If the acres burned by wildfire doubles from 25 to 50 acres (10 to 20 ha), the C + NVC is -$146,252.

SUMMARY

The selection of a fire management strategy for a wilderness area has definite economic implications of which the informed land manager must be aware. In some cases, economic impacts of alternative fire management strategies can be compared by examining the costs of the programs. In other cases, fire management activities can impact the environment in a manner that affects the flow of market goods. In the second instance, cost plus net value change is an appropriate model for examining economic impacts.

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COOPERATIVE FIRE PLANNING FOR LARGE AREAS: A FEDERAL, PRIVATE, AND STATE OF ALASKA EXAMPLE

Dale L. Taylor, Frenchie Malotte, and Douglas Erskine

ABSTRACT: Alaska land managers and wildfire protection organizations have begun interagency fire planning for over 220 million fire-prone acres (≅81 million ha). A 14-step process has been developed to guide planning teams. Four plans have been completed and nine are presently being developed. They will cover all major fire-prone areas of the State by 1984. Thus far, land managers have collectively placed approximately one-fourth of their land under full protection, one-fourth under modified protection, and one-fourth under limited protection. The remainder is nonburnable. Results from an active 1983 fire season indicate lands are placed in appropriate protection categories.

INTRODUCTION

Alaska land managers and wildfire protection organizations have begun to change policies intended to protect surface resources from wildland fire. The change in policy occurred when managers recognized that more cost-effective fire management is needed (U.S. Department of the Interior 1979). Suppression personnel were among the first to question cost effectiveness. Recent studies have revealed damage done by some suppression techniques (DeLeonardis 1971; Bolstad 1971). Welbourn (1983) reported an increase in length of fire cycle of 2.7 times the presuppression cycles. We feel that this change will result in loss of nonforest, hardwood, and mixed forest vegetation types as well as decreases in fuelwood, net productivity, and the amount of manageable forest land. Studies of wildfire statistics (Barney 1969), a review of fire suppression in Alaska (Pyne 1982), and a synthesis of the literature on fire effects (Viereck and Schandelmeier 1980) also influenced the change in fire protection.

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The completion of these studies coincided with Congressional action that provided for massive land transfers and for new land managers in Alaska. These new managers are sponsoring interagency planning that departs from the traditional policy of automatic and aggressive suppression response.

The purpose of this paper is to describe the rationale for an interagency approach, the planning process being applied, and the impacts and mitigation of conflicts resulting from the approach.

It is important to realize that land and resource management plans do not yet exist in many parts of Alaska. The planning decisions being made in this cooperative effort are not considered equivalents of these plans but are interim guides for fire suppression activities until comprehensive planning is completed. As new land management plans are completed, fire protection requirements are incorporated.

THE ALASKA FIRE COMPLEX

When considering wildland fire management in Alaska, the size of the State (375 million acres [152 million ha]), the inherent fire regimes, the influence of wildfire on northern ecosystems, the major actions that created mixed ownership patterns, and the evolution of protection programs and organizations are important factors.

Although Alaska is large, its population is only about 465,700 people. Over half of this population is concentrated in the urban areas of Anchorage and Fairbanks. Much of the remaining population is concentrated along the road network, the rail belt, and in the south-central portion of the State. Additionally, hundreds of villages and isolated dwellings are scattered across remote sections of the State where access is limited to air and water travel.

To describe Alaska, a number of methods for dividing the State have been used. Included are climatic zones (Searby 1968), fire weather zones (Trigg 1971), ecoregions (Bailey 1978), and physiographic divisions (Wahrhaftig 1965). Wahrhaftig's physiographic divisions are useful for fire history purposes (Gabriel and Tande 1983).

Searby (1968) describes a variety of climatic zones. These are a Maritime zone, which includes southeastern Alaska, the South Coast, and southwestern islands; a transition zone between marine and continental influences; a continental zone that covers the Interior Basin; and an arctic zone that covers the area north of the Brooks Mountain Range.

The vegetation pattern is diverse and varies by climatic zone. In the Maritime zone of the southeastern panhandle, a closed-needleleaf forest occurs; it consists of Sitka spruce-mountain hemlock-western hemlock in proportions that vary, depending upon site. North of the Brooks Range and along the western coastal areas in the arctic zone are mesic graminoid herbaceous plant communities that are underlain by permafrost.

Within Alaska's 375 million acres (152 million ha), approximately 220 million acres (89 million ha) are considered vulnerable to wildfire. To describe generalized fire regimes, the State is divided into geographic areas (fig. 1):

Southeast Alaska: Primarily human-caused fires occur in this Maritime zone. Fewer than five fires occur per year. Burning intensity is moderate to low.

Arctic and West Coast: Lightning is infrequent; human-caused fire occurrence is low. Burning intensity is moderate to low. In some years, however, the Seward Peninsula can experience large fires.

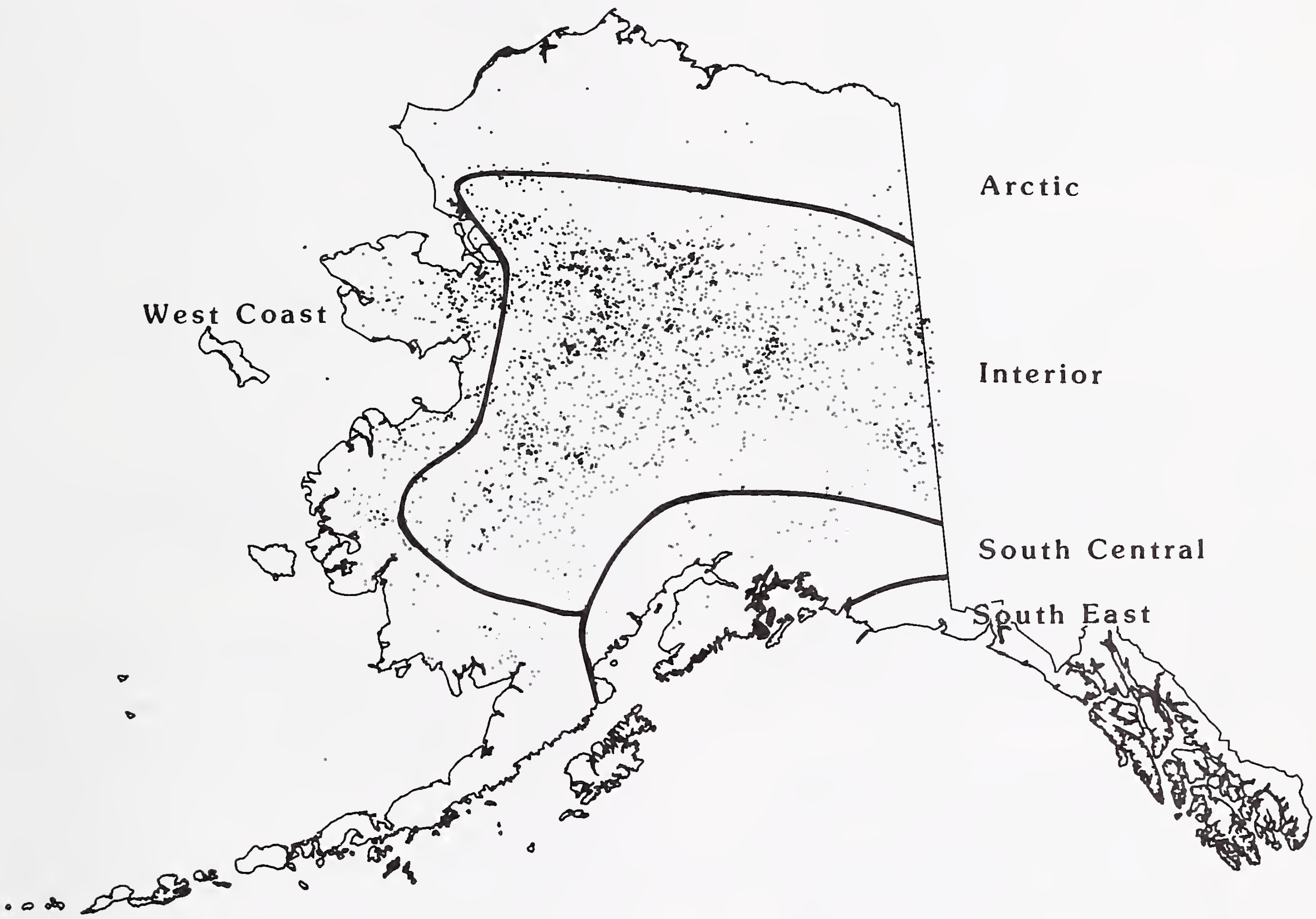

Figure 1. Distribution of lightning-caused fires in Alaska. (Data from Gabriel and Tande 1983.)

Vegetation types in the Interior are white spruce forest on well drained, permafrost-free soils and extensive stands of black spruce forest. Black spruce forests are interspersed with mesic graminoid herbaceous plant communities on poorly drained soils underlain by permafrost. Generally, elevations above 2,000 to 3,000 feet (600 to 900 m) do not support plant cover that presents a fire problem.

South-Central: The south-central area is within the transition zone between marine and continental influences. Numerous fire incidents occur annually, with the majority being human-caused. The intensity is moderate to extreme, depending upon weather. Resistance to control is moderate to high. The wildland-urban interface constitutes a major suppression concern.

Interior: The Interior is a region of high lightning occurrence, with incidental, human-caused fires along roads, railways, and near villages. Burning intensity and resistance to control is moderate to extreme. Fire size is influenced by the remote nature of the area. Access is primarily by air. The region is warm and dry and experiences heavy lightning activity during summer months. A fire of more than 1 million acres (400 000 ha) has been recorded.

The fire protection program has been administered by the Bureau of Land Management. Organized efforts began in 1946 following several years of sporadic protection along the rail belt and road network (Pyne 1982). The current fire protection program has been developed in the last two decades, as compared to seven decades in other states. Before organized suppression efforts, an estimated 1.5 to 2.5 million acres (600 000 to 1 million ha) burned annually (Barney 1971). Suppression efforts since 1969 have reduced the annual acres burned from 625,000 acres (250 000 ha) to 375,000 acres (150 000 ha), or about 75 percent.

The Alaska Statehood Act of 1959, the Alaska Native Claims Settlement Act (ANCSA) of 1971, and the Alaska National Interest Lands Conservation Act (ANILCA) of 1980 are Congressional actions that have significantly influenced the fire protection program. These acts transferred 104 million acres (42 million ha) to the State and 44 million acres (18 million ha) to the Native corporations, and created a number of federal conservation units totaling more than 100 million acres (41 million ha). Five federal land managing agencies, the State, Native village, and 12 regional corporations, private individuals, the United States Army, and the United States Air Force now comprise the land management community. The land allocation process will not be completed for several years, which further complicates fire protection response.

Wildfire suppression is administered by three agencies. To prevent organizational duplication, each suppression organization protects its respective lands under a cooperative suppression agreement with a contractor-client relationship. To facilitate these agreements, protection requirements and standards are being developed through interagency fire plans. This permits land managers who must meet individual agency goals and mandates to guide the fire protection decision process before the fire starts. The vast and remote character of Alaska, coupled with the small management staffs available, makes management input difficult at the initial attack stage.

One uniformly accepted objective of fire management planning is to reduce fire suppression costs. It is commonly agreed that overall costs associated with suppressing all fires in Alaska has reached the point of diminishing returns and must be reduced. Furthermore, it is known among land managers that some fires do not adversely impact natural resources and, in some cases, damages from suppression action are greater than from the fires.

Resource managers have also been taking a harder look at the beneficial roles of fires. In Alaska, fires promote decomposition and nutrient cycling and help maintain vegetation diversity. The vegetation diversity in turn supports a diversity of wildlife--one of the most important surface natural resources in the State and of considerable economic significance. Fire, then, is an integral force in determining wildlife habitat and populations of wildlife, and as such deserves the just considerations of fire managers in weighing both beneficial and damaging effects.

THE FIRE PLANNING PROCESS

The Alaska Land Use Council (ALUC), a group of top Federal, State, and Native land managers authorized by ANILCA, established a fire-working group to develop interagency protection goals and objectives, categories of protection, and complementary suppression strategies. The effort resulted in the development of the Alaska Interagency Fire Management Plan (AIFMP). The ALUC adopted the AIFMP as the model for Alaska. The Alaska Interagency Fire Management Council (AIFMC) was then formed by Memorandum of Understanding to facilitate the task of Statewide fire planning (fig. 2).

Goals and Objectives

A significant step in the development of the planning process was the ability of agencies to compromise on the goals and objectives for fire plans as follows:

The purpose of the plan is to provide an opportunity through cooperative planning for land managers to accomplish their fire-related, land-use objectives in the most cost-effective manner. These objectives will be accomplished by establishing broad fire management strategies for unplanned wildfires that will reduce suppression costs (compared to the past suppression only policy) to a level commensurate with the value of protected resources. Management options should be ecologically and fiscally sound, operationally feasible, and sufficiently flexible to be changed as objectives, information, and technologies change.

The objectives of this plan are to ensure:

- o Aggressive and continued suppression action will be taken on fires that threaten human life, private property, and human-made developments.
- o Levels of fire suppression and dollars spent on fighting fires should be commensurate with the value of the resource warranting protection.

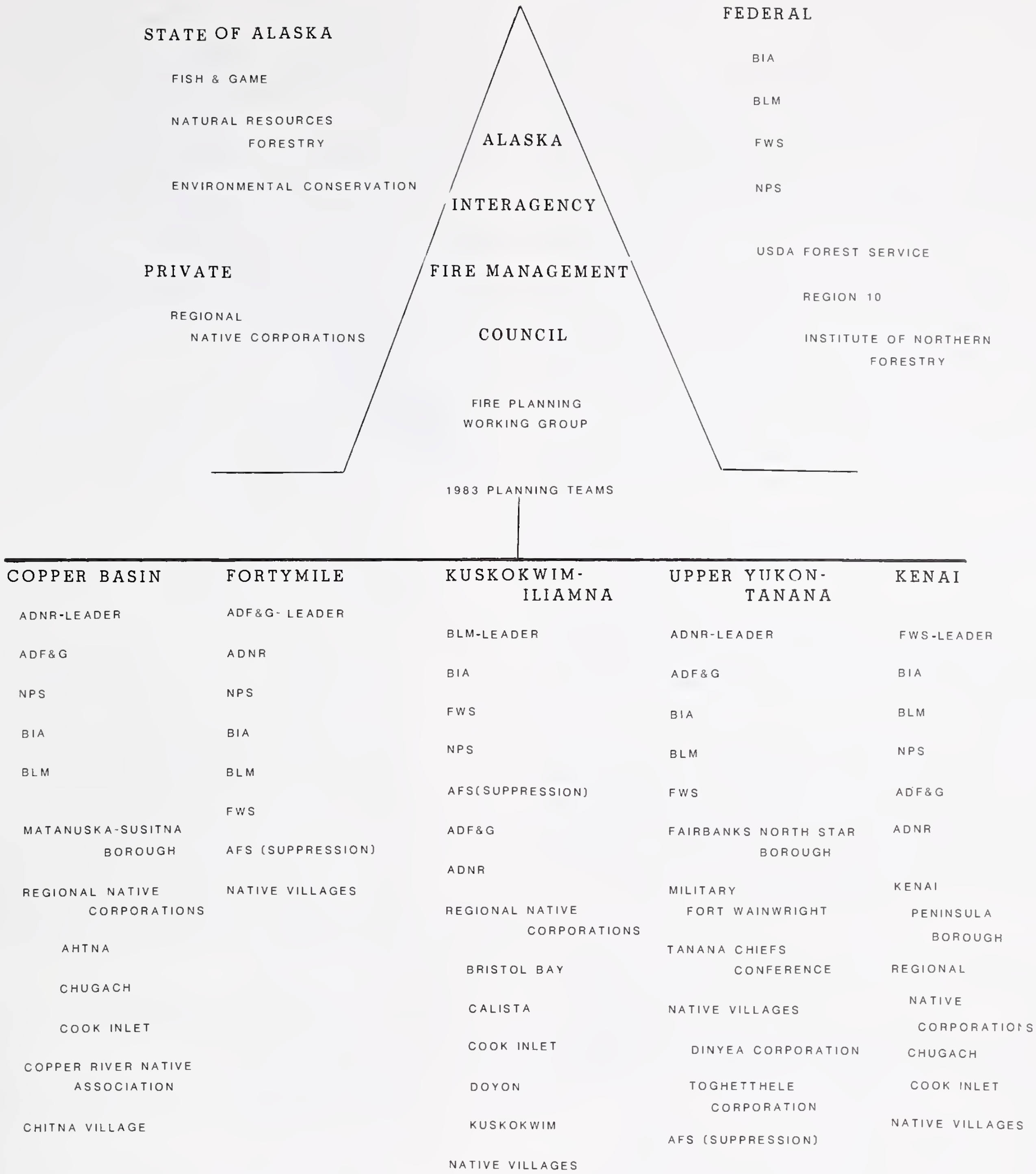

Figure 2. Membership on the Alaska Interagency Fire Management Council, and membership on the five planning teams the Council sponsored during 1983.

- Selection of fire management options will optimize the ability of the land managers to achieve their agency management objectives for lands and resources they administer.

Uniform definitions are required because of complex landownership and because suppression organizations must respond to different landowners within their designated protection areas. As a result, the following defined and agreed-upon fire management options allow land managers to realize individual objectives and mandates. Selection of these options helps establish priorities of where suppression forces are to concentrate their activities. Land managers can also stipulate suppression constraints on their lands within each option. Four management options, in order of priority, are available:

1. The critical protection option is designed for specific sites where human life or habitation are present. These sites receive immediate, aggressive, and continued attack to minimize damage. Protection of critical sites is the highest priority for suppression forces.

2. <u>The full protection option</u> identifies areas of high natural resource value. Wildfires will be controlled with immediate and aggressive action to minimize acres burned.

3. <u>Modified action option</u> provides for initial attack on all new fire starts during the severe burning portion of the fire season. Fires that escape initial attack are evaluated by the suppression organization and the affected land manager(s) using an escaped fire analysis to determine further appropriate control strategy. Strategies are employed that consider the trade-off of acres burned versus suppression expenditures. The modified option is designed to provide opportunities, during the low-risk period, for fire to complement management objectives. A predetermined date, derived from historical fire occurrence, is used to initiate a cooperative decision between land managers and the appropriate suppression organization on the termination of initial attack activities.

4. <u>The limited action option</u> is available for areas where fire activity is desirable or where resource values do not warrant suppression expenditures. Suppression activity is limited to the prevention of escape from the designated area. Monitoring of fire behavior and spread is essential to allow time for developing and implementing contingency plans.

A handbook entitled "Alaska Interagency Fire Planning Guidelines" has been developed. It includes the organizational structure and the relationship between planning teams and the interagency community. As process and products evolve, the handbook will be revised to accommodate new ideas and changes that have Statewide impact.

Fourteen steps guide planning teams. They are as follows:

1. The team is organized. Appointed representatives are called together and briefed by the Fire Planning Working Group (FPWG).

2. The planning area boundaries are refined. Major urban areas are excluded, and an attempt is made to maintain administrative and political land units. An agreement between Canada and Alaska is included to accommodate planning areas adjacent to the international boundary.

3. Management units within the planning area are delineated to refine analysis. Watersheds, geographic features, and general fire history are used as parameters.

4. General landownership patterns are identified to facilitate selection of management options.

5. Fire occurrence is analyzed by management unit. Total number of fires by cause, size, date of occurrence, behavior, and cost for the period of record (1957-83) is considered.

6. Critical sites are identified on 1:63,360 scale USGS quadrangle maps.

7. Natural and cultural resource values warranting special suppression consideration are identified and inventoried on 1:63,360 scale USGS quadrangle maps.

8. Preliminary fire management option selection is completed. Identifiable geographic features, where fires can be controlled, are used as boundaries.

9. Public meetings are conducted to obtain suggestions on management options, review accuracy of the data, and identify public concerns.

10. Review is provided to AIFMC, fire suppression organizations, and signatory levels of the involved land managers. The purpose of the review is to validate preliminary decisions and to facilitate approval of the final decision document.

11. Conflict resolution and final management option selection are completed. Team leaders are to facilitate conflict resolution between individual land managers, particularly in areas where full and modified protection are adjacent to the limited action option. If necessary, unresolvable situations are referred to the affected line officers or agency heads for resolution.

12. The environmental assessment contained in the model plan has been approved as a regionalized programmatic statement. For Federal agencies, a "finding of no significant impact" is provided as a part of the signature page.

13. Final printing and signing of the document is coordinated by the AIFMC.

14. Implementation occurs after team delivery of the following to the suppression organization(s): (1) 1:250,000 scale base map for the planning area depicting generalized management option boundaries and gross land status; (2) 1:63,360 scale quadrangle maps of the planning area that show management options and significant resources identified in step 7.

To facilitate agency workload and maintain a manageable approach, the State is divided into general areas ranging from about 5 million acres (2 million ha) to over 40 million acres (16 million ha) (fig. 3). Lightning-prone areas receive first priority. A primary consideration is to decide in which areas savings can be realized by reducing suppression commitment.

Public meetings are held to satisfy NEPA requirements as well as to inform the general public of the changing program. Information is dispensed

Figure 3. The 14 fire planning areas in Alaska. Completed areas are shown with management units drawn in, uncompleted areas are blank. All named areas are to be completed by 1984.

through special mailings to various interest groups, including State and Federal legislators.

Positive responses to the plan have been received from the Alaska Congressional delegation and State legislators. The Alaska Board of Forestry passed a resolution to support this approach to fire protection.

RESULTS

Four fire plans have been completed that cover approximately 109 million acres (44 million ha) (table 1). These include the Kuskokwim-Iliamna, Copper Basin, Fortymile, and Tanana-Minchumina planning areas (fig. 3). The plans for Upper Yukon-Tanana area, 44.7 million acres (18 million ha), is nearing completion. After May 1984 the Kobuk, Seward Peninsula-Koyukuk, Kenai Peninsula, and Lower Kuskokwim-Anvik areas should be finished. The nine plans will cover the most fire-prone region of the State (fig. 1).

Thus far, land managers have cooperatively selected lands for approximately one-fourth full protection (23.9 percent), one-fourth modified action (21.7 percent), and one-half for limited action (54.5 percent (table 2). Not all lands placed in the limited category are burnable. Nonburnable areas of ice, rock, and water reduce the fire-prone acreage to 25.5 million acres (10 million ha), or 23.3 percent of the area. Thus, the fire-prone portion of the limited option covers approximately one-fourth of the acreage under plan.

Although fire activity in 1983 was not sufficient to test completed plans, a total of 78 fires covering 46,124 acres (18 666 ha) were recorded within the planned areas (table 2). Results from the 1982 and 1983 fire seasons provide some indication of potential cost savings. Average cost (adjusted for inflation) per fire in the Tanana-Minchumina fire planning area was about $25,000 for the period when all fires were being suppressed. Assuming monitoring costs at 50 percent

Table 1.--Number of acres in suppression categories by fire planning unit[1]

Planning area	Size	Management option: Full		Modified		Limited		Fire-prone limited	
	Million acres	Million acres	Percent	Million acres	Percent	Million acres	Percent	Million acres	Percent
Kuskokwim-Iliamna	42.5	8.2	19.3	9.7	22.8	24.6	57.9	9.8	23.0
Copper Basin	19.8	2.2	11.0	.8	4.0	16.7	85.0	5.0	25.0
Fortymile	17.0	6.7	39.0	1.0	6.0	9.3	55.0	5.2	31.0
Tanana-Minchumina	31.0	9.0	29.0	12.4	4.0	9.0	29.0	4.5	14.5
Totals	109.3	26.1	23.9	23.9	21.7	59.6	54.5	25.5	23.3
(Million hectares)	(44.2)	(10.6)		(9.7)		(24.1)		(10.3)	

[1]Critical areas are site-specific and are not tabulated. Fire-prone portions of the limited option are listed for illustration.

Table 2.--Fire activity by management option and landownership in four planned areas, 1983

Land manager	Option	Tanana-Minchumina No. fires	Tanana-Minchumina Acres	Kuskokwim-Iliamna No. fires	Kuskokwim-Iliamna Acres	Fortymile No. fires	Fortymile Acres	Copper Basin No. fires	Copper Basin Acres	Totals No. fires	Totals Acres
BLM	Limited	10	[1]131	0	0	(Not implemented)		0	0	10	131
	Modified	7	72	0	0			0	0	7	72
	Full	18	125	0	0			1	3	19	128
NPS	Limited	0	0	0	0	5	322	0	0	5	322
	Modified	0	0	0	0	2	1	0	0	2	1
	Full	1	1	0	0	1	3	0	0	2	4
FWS	Limited	2	12	2	12,650	(Not implemented)		(No land in the area)		4	12,662
	Modified	0	0	0	0					0	0
	Full	0	0	2	3,515					2	3,515
Native	Limited	0	0	0	0	(Not implemented)		0	0	0	0
	Modified	0	0	0	0			0	0	0	0
	Full	[2]4	183	0	0			2	1	6	184
State	Limited	5	1,302	1	10	(No fires after implementation)		1	1	7	1,313
	Modified	6	27,784	0	0			0	0	6	27,784
	Full	4	4	0	0			4	4	8	8
	Totals	57	29,614	5	16,175	8	326	8	9	78	46,124
	(Hectares)		(11 985)		(6 546)		(132)		(4)		(18 666)

[1]Eight fires in limited were attacked as full suppression fires between June 24 and July 7.

[2]Includes one critical site fire.

of suppression costs for each fire the net savings would be about $200,000 in the planning area during 1983. Average initial attack costs are not available for comparison.

National Park Service managers feel the fire management plans have reduced suppression costs. For example, in 1981, Wrangell St. Elias National Park and Preserve experienced a 13,000-acre (5 261-ha) fire that cost $2.1 million to suppress. A fire management plan has since been approved that places that fire area in the limited option zone. Monitoring the fire would have cost an estimated $25,000. The same year the Park experienced a second fire which burned 20 acres (8 ha) and was allowed to burn under an interim fire plan. Monitoring costs totaled $600. It is estimated suppression would have cost about $20,000. In 1982, a 6,100-acre (2 470-ha) fire was allowed to burn in Denali National Park under a fire management plan. Suppression managers mistakenly placed six smokejumpers on the fire and immediately requested eight additional jumpers and an aerial retardant drop. At that point, the error was noted and suppression action terminated. Initial suppression action cost $3,000, and the additional forces would have added another $10,000. Continued suppression action would have included associated support and demobilization costs. Total expenditure for full suppression was not estimated. The fire burned for several weeks with a monitoring expense of $13,000.

The Alaska Department of Natural Resources did a cost analysis on the Munson Creek Fire that burned from June 2 through June 15, 1983 (State Forester memorandum to Commissioner of Natural Resources, June 15, 1983). The fire was located within the incompleted Upper Yukon-Tanana Planning Area that was not covered by a completed plan. Traditionally, the fire would have received aggressive suppression action until controlled. Preliminary fire plan decisions, combined with onsite evaluations by affected land managers, resulted in a strategic control plan that reduced suppression action. Suppression costs saved on this fire have been estimated at $1.2 million.

There will be a continuing assessment of cost savings versus expenditures on individual wildfires that could have been suppressed when small but were allowed to burn and finally were contained following a later decision. The costs of subsequent confinement actions are an issue that land managers must balance against resource benefits received.

The interagency approach has provided an important opportunity for land managers to exchange personal views and agency philosophies. These exchanges have resulted in a cooperative spirit and better communication among land managers.

IMPACTS AND MITIGATIONS

The process of bringing about the change in fire protection on 220 million acres (≅81 million ha), and the change itself, have several impacts on the State and communities. Among them are increased smoke and potentially fewer jobs.

The smoke issue could undermine an ecologically sound suppression policy that would compromise our ability to protect the critical and full option areas. The issue is not a function of individual fire plan development because suppression activities are managed on a Statewide basis. The Department of the Interior Secretarial Order (3077 dated March 17, 1982) established the Alaska Fire Coordination Group and set the stage for interagency evaluation of each season's activity. The group is formally chartered to coordinate the interagency wildland fire suppression activities in Alaska. Comprised of representatives from regional federal-level fire management staff, the State of Alaska, and the Native community, a forum has been established to monitor the impact of smoke levels. The decision to alter direction Statewide is managed on a continuing basis and rests with this group.

The suppression job in Alaska is performed with a seasonal work force. The decrease in the fires fought can be perceived as a reduction in available wages for firefighters. This is especially important for Alaska because Native suppression crews are hired on a yearly basis. Historically, an active fire season can provide as much as $5 million to $8 million in revenue to the seasonal work force. Fire planning will not necessarily reduce the work force, but it will concentrate firefighters in areas needing protection.

Terminology used in the plans has conflicted with individual agency terminology. The term "limited" has been the most controversial. The term was selected because it best describes the intent of the option, that is, to limit suppression activity to a monitoring mode. Administrators have clarified the issue by stating that monitoring to assure fire containment within limited areas is an appropriate suppression function.

Obtaining consensus on fire plan objectives was difficult and time consuming. Individual agency objectives and goals for fire management, the diverse stages of program development within agencies, and the uncertain results of an interagency approach led to lengthy debate. The final objectives obtained through compromise required approval at the agency head level. The development of plan objectives suitable to all agencies and organizations required broad definitions and goals that focused on fire suppression activities, which give agencies the latitude necessary to independently develop other fire management activities such as prescribed burning and hazard reduction.

The rapid change from a program that automatically suppressed all fire starts to one that must consider several suppression levels presents a host of operational problems. Prominent are:

--Size of planning units has affected map storage and retrieval. Display of site-specific information required over 6,000 USGS 1:63,360 quadrangle maps to cover Alaska. The Kuskokwim-Iliamna plan required 380 map copies. Map duplication is expensive, and revision is difficult. As an interim step, resource data and management options are placed on the maps, digitized, scaled to township size, and photographically superimposed on Master Title Plats of legal land status. Aperture cards containing the composite are easily and inexpensively duplicated and distributed to dispatch offices. This approach is necessary until an automatic data processing program is completed. Mutual funding has made this approach possible.

--Natural barriers are often nonexistent or inadequate to effectively isolate protection categories. Being prepared to conduct large backfire and burnout operations will require modifying organizational structure.

--The risk of allowing fires to burn unimpeded, given the possibility of major weather changes, has been minimized by neighboring land managers. Option boundaries are established through compromise.

--Significant blocks of land in Alaska have been selected for eventual ownership by one or more entities. Until conveyence is completed, these blocks are being managed on an interim basis by the various federal agencies. This management situation presents unique liability questions that will be unresolved for some time.

Maintaining presuppression funding in support of a Statewide organization that can prevent escape of large fires from designated areas is a justifiable concern. Applying less than full suppression significantly alters the tactical requirements. Detection, monitoring, and containment require presuppression funding to pay for training, staffing, and equipment purchases. This workload has not been fully identified and a method of analysis must be developed. Budget and management personnel must realize that reducing the number of initial attack actions does not necessarily directly reduce budget levels.

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THE PARK-CARIBOU PLAN: AN EXAMPLE OF INTEGRATED PLANNING

John R. Swanson and Alan E. Denniston

ABSTRACT: The Lassen Fire Management Plan (Park-Caribou Unit) was a successful interagency planning effort between Lassen Volcanic National Park and Lassen National Forest in northern California. A single cohesive interagency planning team was the key to success. Other factors were adherence to informal as well as formal planning processes, early involvement of the public, and developing accountability for planning tasks.

INTRODUCTION

> It seemed that everytime we were beginning to form up into teams we would be reorganized. I was to learn later in life that we tend to meet any new situation by reorganizing; and what a wonderful method it can be for creating the illusion of progress while producing confusion, inefficiency, and demoralization. (Petronius, Arbiter 210 B.C.)

Two thousand years later, many of us can relate to how Petronius felt. But reorganizing may be appropriate for any new task. The Lassen Fire Management Plan exemplifies reorganization that provided clarity, efficiency, and a stronger interagency bond.

Lassen Peak dominates much of northern California. In 1914 and 1915, it also dominated the news throughout most of the country when its spectacular volcanic eruption spewed ash several miles into the air and created thousands of barren acres that today are slowly revegetating with Jeffrey pine. Until 1980 when Mount Saint Helens blew, it was North America's most recently active volcano.

In 1916, Congress designated the volcano and the surrounding 100,000 acres (≅40 500 ha) as a national park, administered by the U.S. Department of the Interior's National Park Service. For more than 75 years, over two-thirds of the Park has been managed for its wilderness character.

Adjacent to the Park's eastern boundary lies another 20,000 acres (≅8 100 ha) of upper elevation forests and meadows that have been managed as wilderness since 1907. Today it is the Caribou Wilderness, administered by the U.S. Department of Agriculture, Forest Service.

THE GREAT ABYSS

Lassen Volcanic National Park and Caribou Wilderness have many similarities. They both occur on flat glaciated volcanic soils. Cinder cones and old volcanic plugs provide the major topographic relief. Scores of lakes dot the area. A mosaic of vegetative species and age classes covers the landscape. Ponderosa pine (*Pinus ponderosa*) and Jeffrey pine (*P. jeffreyi*) clothe the lower drier sites. Red fir (*Abies magnifica*) and white fir (*A. concolor*) occupy middle elevations and cover about a quarter of the area. Lodgepole pine (*P. contorta*) occupies another 25 percent of the Park and Caribou Wildernesses. Mountain hemlock (*Tsuga mertensiana*), western white pine (*P. lambertiana*), and whitebark pine (*P. albicaulus*) are found at the highest elevations. Grassy meadows and fields of montane chaparral (composed of several brush species, most of which are important to wildlife) occur as small patches scattered throughout a vegetative mosaic. Seventeen thousand acres (≅6 900 ha) surrounding Lassen Peak are barren or nearly so.

Wildlife

A diverse array of wildlife species and habitats exists within the area. Portions of several large migratory deer herds use the area for summer range. Bald eagles nest in Lassen National Park and forage in the Caribou Wilderness. Peregrine falcons arrive in the late summer after breeding elsewhere. The spotted owl, wolverine, red fox, osprey, goshawk, fisher and pileated woodpecker occur in small populations. Black bear, pine marten, and a number of other vertebrate species are common inhabitants.

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Visitor Use Patterns

A well-used highway winds its way from north to south past Lassen Peak in the western quarter of the Park. Except for this road and three others that end at campgrounds a mile or two inside the park boundary, the only access is by wilderness trail. More than 2,000 recreationists visit the Caribou Wilderness each year; 12,000 additional users enjoy the Park wilderness areas. Well over 200,000 visitors drive through the park annually. Most come to hike, fish, camp, view the scenery and wildlife, and to climb the easy trail up Lassen Peak. Because the wilderness areas are generally considered to present little challenge, they attract many inexperienced campers. Local visitors from the small forest-oriented communities nearby frequent the Caribou and Park because of handy access and relatively good fishing.

Experiences within the Park's developed areas are less rustic. The area around Juniper lake is a popular place for summer residences. Developed campgrounds border several large lakes near the Park boundary. Administrative sites at Park entrances and Ranger Stations attract visitors seeking information. No developments exist in the Caribou, but summer residences ring Silver Lake, which abuts the wilderness on the east. High-quality commercial forests surround both the Park and Caribou. These developments require protection, increase the need for public input, and make planning more complex.

Resource Management Objectives

The 1964 Wilderness Act decreed that areas such as the Lassen and Caribou Wildernesses be administered to perpetuate the wilderness resource, specifically by retaining the area's primeval character and influence. Management must ensure that human use and influence do not interfere with natural forces or processes in the ecosystem.

The basic resource management objectives are essentially the same for both agencies: manage for the perpetuation of natural processes and provide for the protection of human safety and property. In the Park, the intent is to restore and maintain the terrestrial and aquatic ecosystems as they probably existed before technological man disturbed them (U.S. Department of the Interior, National Park Service 1983). The goal in the Caribou Wilderness is to perpetuate the wilderness resource and leave it unimpaired for future use and enjoyment as wilderness (U.S. Department of Agriculture, Forest Service 1976).

Fire Management

Fire is an important natural element that has been inadvertently excluded during the past 70 years because of effective suppression efforts. Burned snags, catfaces on tree boles, and abundant charcoal everywhere on the forest floor show that fire is no stranger to the Park and Caribou. We used increment borers to core fire scars (Arno and Sneck 1977) and found an average fire return interval of 7 to 21 years in the Jeffrey pine and nearly 70 years in other habitats. It appears that small surface fires burned frequently in the Park and Caribou Wildernesses. These 1- and 2-acre (0.4- and 0.8-ha) fires only left fire scars, though they may have flared up in spots with heavy fuel accumulations and torched the crowns of trees occurring singly or in small groups. Other surface fires would have been less intense and would have left no signs. Evidence suggests that large fires covering thousands of acres may have occasionally burned through the wilderness.

Fire suppression efforts began around 1914, and became increasingly effective. One to six fires have been detected each year ever since. Aggressive suppression has, however, caused some wilderness deterioration. Burning trees and snags are not always a significant threat, yet they are routinely felled and mopped up. Potential raptor nesting sites and habitat for snag-excavating birds may suffer from this practice. Whitebark pine on the semibarren slopes of Lassen Peak are frequently struck by lightning. Suppression requires that a burning tree be felled, a line constructed around it, and all fire extinguished. Because of thin soils, steep slopes, and lack of ground cover, these actions cause serious erosion.

The most obvious and perhaps most serious effects of fire exclusion are indirect: A dense understory of white fir is sprouting under all but the highest elevation timber stands; chaparral brushfields, which grew up after fires, are disappearing because of conifer encroachment. With them goes important wildlife habitat that is not being replaced.

In the absence of fire, lodgepole pine invades meadows from stands along the fringes. Fire probably played a role in maintaining these meadows, which constitute important habitat for small mammals and raptors. These meadows also attract wilderness users because of the profusion of wild flowers and their intrinsic beauty.

With the absence of fire, succession would greatly alter species composition and structure. Fire-resistant habitat types that have survived in these areas for eons would be replaced by more fire-susceptible species. This tendency, and continued fuel accumulation, makes an unusually large and intense fire more likely. Such a fire could cause uncharacteristic effects and changes to occur in the wilderness ecosystems.

The Lassen and Caribou Wildernesses share a uniform geology, similar vegetation and wildlife, parallel use patterns, comparable management objectives, matching fire history and ecology, and a common boundary. Two separate Federal agencies manage these areas. The National Park Service manages the area to the west of the administrative boundary; the Forest service manages the area to the east. It was this split that created the Great Abyss.

BRIDGING THE GREAT ABYSS

In 1979, the National Park Service and the Forest Service each discovered that the other agency was planning to manage fires from unscheduled ignitions[1] ("prescribed natural fires" or "management fires"). National Park Service and Forest Service personnel both had heard of cases where fires under prescription for one agency had to be stopped at the administrative boundary, simply because they were out of prescription for the neighboring managers. This was the result of independent planning and separate management objectives even though the Agencies shared common boundaries, ecosystems, and similar fire responses.

In the spring of 1980, a five-member interagency team from Lassen Volcanic Park and Lassen National Forest attended Advance Fire Management at the National Advanced Resource Technology Center, Marana, Ariz. Although the two agencies frequently met to discuss mutual problems and solutions, this occasion was the first where two agencies had joined together to tackle a common fire management project. The team outlined the formal plan at Marana and decided to create a single implementation plan to be approved and used by both agencies.

The Planning Process

It soon became apparent that two distinct planning processes were involved. One was formal, the other informal. Each proved to be equally important.

The formal process.--The formal process is described in agency manuals. We began with a Memorandum of Agreement in which Lassen National Forest and Lassen Volcanic National Park formally stated their determination to form a single interagency interdisciplinary (ID) planning team with Al Denniston as the team leader. The Park had completed its Natural Resource Management Plan, which identified the need to reintroduce fire to Park ecosystems. The plan fulfilled Council on Environmental Quality regulations (40 CFR 1500-1508), so the Park was ready to prepare a fire management plan immediately.

Lassen National Forest, however, lacked such direction. The agency needed an environmental analysis (EA) of the Caribou Wilderness proposal; therefore, the first task for the newly formed interagency ID team was to complete this analysis and prepare the corresponding environmental assessment. Because of the need for a joint fire management plan, the Park agreed to wait for the environmental assessment to be completed before proceeding with the plan.

[1]Editors' note: please refer to the Foreword for comments on prescribed fire terminology.

Public involvement is an integral part of an environmental assessment. Because Lassen Volcanic National Park was also interested in determining public sentiment about the proposed program, another formal agreement was signed. Its purpose was

> to coordinate public, external agency and in-service information and sensing opportunities relative to natural fire management planning . . . .

A newsletter series, a slide-tape program, numerous newspaper articles, a television interview, and a dozen public workshops provided information to the public. The public workshops and wilderness users' responses were useful in assessing public concerns.

Gryson (1981) analyzed in depth the comments received. We found that newsletters were our most effective public information tool. Public comments were best gathered during meetings at which we solicited on-the-spot verbal input. This input was written on large charts in order for all persons to understand the issues. The poorest input came from public workshops where we supplied response forms to be returned later.

The environmental assessment (Forest Service 1981) was completed almost a year after our trip to Marana. An abbreviated version of the ID team, assisted by a dozen contributors, prepared the implementation plan. It was approved by the Forest Service's Regional Forester and the Regional Director of National Park Service's Western Region in the fall of 1982 (National Park Service and Forest Service 1982).

The informal process.--The formal process was necessary for administrative reasons, but the informal planning process was crucial to complete the plan. This was especially important since federal machinery is moved primarily by budget allocation and targets. We had neither. Three elements of the informal process contributed to successful completion of the project: fostering teamwork, laying groundwork with the administrative hierarchy, and managing grassroots involvement.

Fostering teamwork.--Complementary personalities and determining accountability for specific tasks fostered the teamwork we needed. Agency identities were forgotten whenever the ID team met. This was especially valuable when Al Denniston, a Park Service employee, led the team doing an EA for the Caribou Wilderness--land administered by the Forest Service. A shared conviction to reintroduce fire under conditions appropriate to the wilderness ecosystems made accountability easy. We identified tasks, due dates, and responsible parties and tracked them on a task list that was updated every couple of months. All major tasks, from calling the first ID team meeting to seeking approval of the final implementation plan, were listed. Assignments that were a long way off were kept

rather general. As their due date approached, any associated subtasks were assigned. For example, we noted the following on the first task list we devised in 1980.

Task	Due date	Person
Complete implementation plan	7/4/82	Planning team

In June 1981, we broke that task into its significant subtasks and assigned due dates and responsible parties:

Task	Due date	Person
Design decision matrix	1/1/82	Johnson/Denniston
Write prescriptions	3/2/82	Swanson/Merrifield
Write monitoring and evaluation chapter	3/1/82	Weston/Judd
Design cover	4/1/82	McHargue
Write public inform & involve chapter	4/1/82	Pritchard
Complete implementation plan	7/4/82	Planning team

Laying groundwork.--Throughout the nearly 3 years of planning, we laid solid groundwork for plan approval with the administrative hierarchy. We consulted fire management planners in the Regional Offices of both agencies early in the planning phase and conferred with line officers and fire management officers at the Forest and Park. Rough drafts of the implementation plan were unofficially reviewed by them. In this way, agency officials were aware of the proposed specifics of the implementation plan. Minor conflicts or discrepancies in management philosophies were resolved and agency concerns were solved early before they became roadblocks. Agency commitment, management concerns, and support of agency authorities were established before the final draft was submitted for official review. This facilitated the formal approval stage of planning.

Grassroots involvement.--If laying groundwork with the administrative hierarchy secured commitment to the implementation plan at that level, it was organization and involvement that won support with the administrators at the ground level. It also assured that the most current information was incorporated into the plan. The Forest Service District Fire Management Officer and Park Chief of Resources Management, who would make or strongly influence the decisions to suppress or manage a fire start, designed the decisionmaking scheme in conformance with agency needs. A firefighter with a Bachelor of Science degree in botany, whose avocation is forest fire ecology, wrote a supporting paper on the fire ecology of the vegetative habitat types in the planning area (Husari 1980). The two people most likely to do the fire monitoring studied monitoring schemes from other areas and prepared the monitoring and evaluation chapter for our implementation plan. A District recreation specialist designed the public information and involvement section. In general, those most likely to implement the plan were given the task of constructing the portion of the plan that would directly affect their jobs. The best ideas and directions from existing fire management plans were incorporated where appropriate. Creativity is nothing more than applying somebody else's good idea to solving a new problem. Or, in the words of an anonymous mentor, "skilled plagiarism beats inept innovation every time."

REVELATIONS ON THE OTHER SIDE

We now have an approved fire management implementation plan for the common good. We had six fires the first season and have been able to test the plan early. But the planning is far from over. Our monitoring indicates we may need to refine our prescriptions to ensure we are meeting our management objectives; we still have some procedural bugs to work out.

We can, however, make several observations without hesitation. First, it is important to remember the informal as well as the formal aspect of the planning process. Laying good groundwork early in the game with line officers and others in the administrative hierarchy will foster commitment to the plan. Involving the grassroots levels of the organization will promote a feeling of ownership in the final product and assure that the best-informed individuals have worked on it. Formal "memoranda of agreement" between cooperating agencies clear the way for work to begin.

Second, get the public involved (listening to all viewpoints) early in your planning process. You will get the most from your efforts if you focus on specific, relevant segments of the public such as wilderness users, concerned neighbors, supporters, and detractors. Maintaining their involvement throughout the planning process and keeping them fully informed during implementation are essential.

Third, build accountability into your planning. Clearly identify tasks, set due dates, name individuals responsible for task completion, and document it all. This not only reminds everyone of commitment but also shows line officers how the workload is being shared.

Finally, if you have a future fire management area that is adjacent to land administered by another agency--especially if resource management objectives for both areas are similar--we urge you to reorganize your planning team. Go interagency. Crossing organizational lines informally will ensure that the communication processes are working. When

you roll up your sleeves to go to work, forget the difference in shoulder patches. You will find that cooperation increases efficiency and neighborly esprit de corps and reduces confusion in the long run.

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TRAINING IN SUPPORT OF PARK AND WILDERNESS FIRE MANAGEMENT PROGRAMS

Peter Gaidula

ABSTRACT: Prescribed burning for research purposes began in the California State Park System (SPS) in 1973. In 1980, the SPS began a formal training program in prescribed fire management aimed at producing prescribed fire managers, burn bosses, fire specialists, fire monitors, and crew members. The SPS, like the U.S. Department of the Interior, National Park Service, and the U.S. Department of Agriculture, Forest Service, recognizes the great importance of properly trained personnel for planning and executing prescribed burn programs. This paper describes training program objectives, the duties of prescribed fire personnel, training levels, and criteria for selecting trainees.

INTRODUCTION

It is widely recognized that most wildland ecosystems in California have evolved in the presence of recurring fires. This natural phenomenon was interrupted early in this century when fire prevention and suppression programs began. Restoring fire to its proper role in the ecosystems within units of the California State Park System (SPS) is the major objective of the Department of Parks and Recreation's prescribed fire management program. The department has for some time recognized the potential value of prescribed burning (using scheduled ignitions) as an important tool in managing SPS natural resources. Consequently, prescribed burning within the SPS was initiated in June 1973 at Montana de Oro State Park on the central coast of California (fig. 1). The purpose of this burn, which covered 35 acres (14 ha), was to reestablish the pristine *Stipa* tall grass prairie through fire and soil improvement and to check invasion of scrub species.

Our next big step forward in prescribed fire use came in 1975 when, under the guidance of Harold H. Biswell, professor emeritus of the University of California, Berkeley, a pilot prescribed burn program began at Calaveras Big Trees State Park in the Calaveras South Grove area in the central Sierra Nevada. This grove of giant sequoia (*Sequoiadendron giganteum*) and the adjacent mixed conifer forests cover 1,200 acres (436 ha).

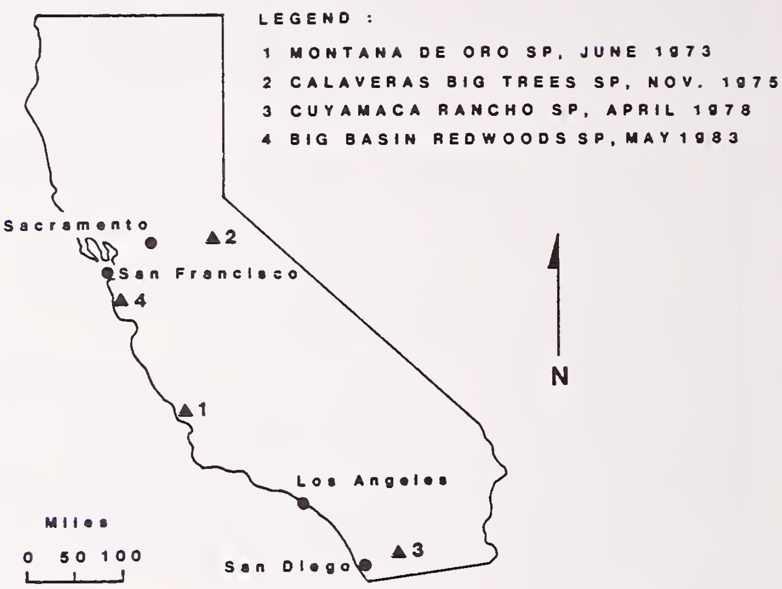

Figure 1.--Map of California showing State Park System units in which the earliest prescribed burning in the System was done. Calaveras Big Trees and Cuyamaca Rancho State Parks have fully operational programs.

Studies show that the giant sequoia requires recurring fire for seed germination and growth (Kilgore 1973). Fire history indicates that this grove, and much of the surrounding forest, has not burned since 1886.

Since 1975, approximately 2,500 acres (1 012 ha) have been treated with fire at Calaveras Big Trees State Park, and plans call for burning most of the 5,500 acres (2 226 ha) comprising this park unit.

After completing research burning on one-fourth-acre (≅0.1 ha) plots in December 1977, pilot prescribed burning began in April 1978 at Cuyamaca Rancho State Park in southern California under the direction of Professor Biswell; at that time, approximately 20 acres (8 ha) in oak woodland and Jeffrey pine forest were burned. Burning resumed in December 1978 and again in the spring and fall of 1979.

Because of a lawsuit against the department, burning was halted until the spring of 1983. Prescribed fire has been used on approximately 500 acres (202 ha) on this unit. The unit covers 24,624 acres (9 965 ha) vegetated by grassland, oak woodland, Jeffrey pine-oak forest, Jeffrey pine forest, mixed conifer forest, and chaparral. Much of this is to be treated with prescribed fire within the next 10 years.

Paper presented at the Wilderness Fire Symposium, Missoula, Mont., November 15-18, 1983.

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On May 9, 1978, at Big Basin Redwoods State Park the first prescribed burn in a coastal redwood unit of the SPS was initiated under the direction of Professor Biswell. Approximately 175 acres (71 ha) of coast redwood forest, chamise-chaparral, and knobcone pine have now been burned. Big Basin Redwoods State Park comprises 15,647 acres (6 332 ha), and a long-range program is now being formulated for prescribed fire.

We estimate that the vegetation (800,000 acres [323 760 ha] in 140 units) would benefit from the use of prescribed fire. Twenty SPS units have been funded during the 1983-84 fiscal year for prescribed fire management planning and data compilation, including the use of fire on small pilot burns.

These initial prescribed burns have provided training for our personnel on an informal, unplanned basis. It became obvious that a more formal training program was needed to provide the expertise necessary to carry out our future prescribed fire management program. Therefore, in the spring of 1980, 12 departmental employees began training under Professor Biswell's guidance.

THE IMPORTANCE OF TRAINING

Restoring fire to wildland ecosystems of the SPS requires persons skilled in the art and science of prescribed burning. Prescribed fire, when used by knowledgeable personnel, can be like an obedient servant, but when used by inexperienced persons, fire can turn into a violent and destructive force. Therefore, the department has established policies to ensure that only qualified and experienced personnel are permitted to plan, supervise, and execute prescribed burn projects within SPS. To accomplish this the department has begun a formal training program in prescribed fire management. The guiding philosophy of this program is that it is better to err on the side of overtraining in the use of prescribed fire.

The importance of training is also emphasized by the National Park Service at Sequoia and Kings Canyon National Parks, which have been applying fire to their ecosystems much longer than our department. Their fire management plan states that:

> The need to ensure that only properly trained individuals are used on prescribed fires is in many respects greater than it is on suppression fires, because any mistakes on fire deliberately started as part of a management program are likely to draw far more criticism than those made during the frequently chaotic fighting of a wildfire (U.S. Department of the Interior, National Park Service 1982).

The National Park Service, Western Region, has recognized the need for prescribed fire job qualifications (National Park Service 1983). In April 1983, that region issued a standardized set of qualifications for prescribed fire jobs with the aim of achieving solidarity and consistency in its training programs. It recognized that such qualifications would add integrity to their national fire programs and ensure that the programs are accomplished in a professional manner.

Another Federal agency that has recognized the importance of prescribed fire job qualifications is the Forest Service (1981), which has established minimum qualification standards for experience and training of personnel in various positions on prescribed fires.

DEPARTMENTAL ORGANIZATION

Before discussing prescribed fire roles and positions, it will be helpful to explain our organizational structure. The California Department of Parks and Recreation, which manages the State Park System, is headed by a director with headquarters at the State Capital in Sacramento. The State has been divided into four administrative regions, each administered by a regional director. Each region has a small technical staff, including one or more professional resource managers. The park system units within each region are administered by area managers and their ranger staffs. It is from these organizational levels that trainees for prescribed fire management are recruited.

TRAINING PROGRAM OBJECTIVES

The objectives of the training program in prescribed fire management are to:

1. Train a cadre of personnel at several organizational levels within the department to plan and execute prescribed fire management programs. The cadre will then instruct others in prescribed fire.

2. Provide within each of four regions sufficient trained personnel to plan, execute, monitor, and evaluate prescribed burn projects.

3. Train three levels of personnel in the prescribed fire management program at each organizational level (area, region, and headquarters) of the department.

The present program was developed to train at least one resource staff person from each regional office and one ranger or maintenance staff person from each region having a unit with a demonstrated need for prescribed fire that has been agreed upon by the department.

PRESCRIBED FIRE POSITIONS

The typical organization and staffing of a prescribed burn project is shown in figure 2. On small burns, several of the roles shown would be vested in one person. For example, the firing specialist may also act as the the prescribed burn boss. The duties of each position (described below) are based substantially on the "Prescribed Fire Job qualification Guide" prepared by the Prescribed Fire and Fire Effects Working Team under the auspices of the National Wildfire Coordinating Group (1979).

Prescribed Fire Manager

Professional resource management personnel at the regional and Sacramento headquarters offices perform the role of prescribed fire manager.

The resource ecologist at the region is the prescribed fire manager, or the program manager, of the region's fire management program. This individual functions as a resource advisor, provides technical service to the field, and works closely with other resource and technical specialists in a planning and advisory role. The fire manager assists in setting resource management objectives for the region's prescribed fire management program reviews plans for the program and advises and assists in the preparation of plans, prepares budget proposals for the program and evaluates the results of the prescribed burn program. The fire manager at the regional level ensures that the prescribed burn boss carries out burn projects according to plan and may become involved in implementing the prescribed fire program.

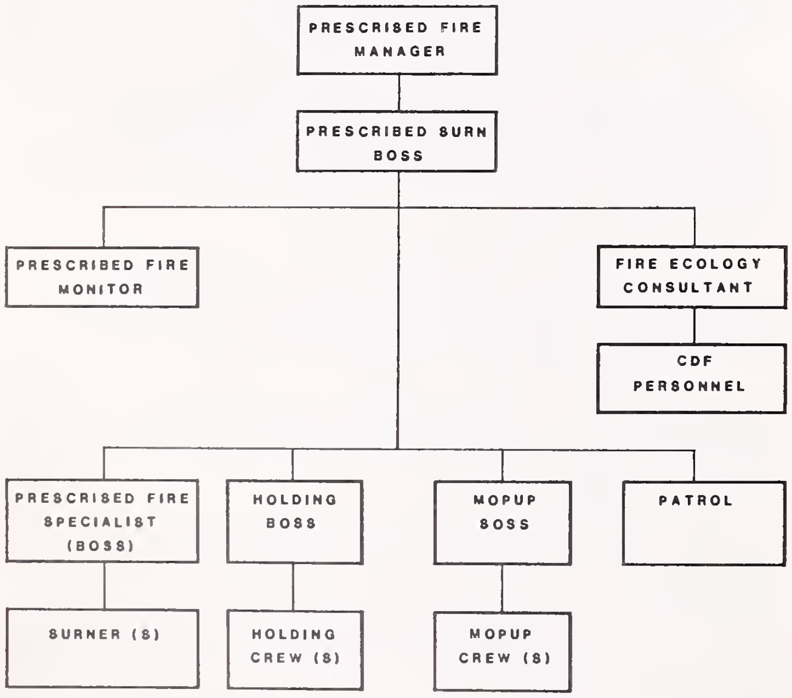

Figure 2.--Prescribed fire project organization. One person may carry out several of the above roles on smaller, less complex burns.

Fire managers at the Sacramento headquarters are involved mainly in broad planning, policy, and review functions related to the prescribed fire management program. They also provide technical services to the field. They may become involved in implementing the prescribed fire management program on selected units of a region.

Prescribed Burn Boss

The prescribed burn boss normally operates at the technician level and is responsible for planning, executing, and evaluating prescribed burns. The prescribed burn boss works closely with the fire manager and supervises the prescribed firing specialist, prepares burn plans, executes burn projects, and evaluates fire results. The burn boss must be knowledgeable in fire suppression.

Prescribed Firing Specialist

The prescribed firing specialist is responsible for igniting a prescribed burn and regulating the intensity of the fire in accordance with the prescribed burning plan. This person can supervise several crew members or personally do the firing, depending on the size and complexity of the burn. This person can assist in project planning and should be knowledgeable in fire suppression.

Prescribe Fire Monitor

The fire monitor collects data for prefire, fire, and postfire periods. This person should have a knowledge of the burn plan and of the fuel and vegetation types within the burn project. This function should be carried out on every burn and may be performed by an area or regional staff member.

Prescribed Fire Crew Members

The prescribed fire crew member serves on the line-holding and mopup crews and also does patrol duty. A crew member may also serve on the firing team or assist in monitoring, depending on the individual's qualifications and the needs at the burn site.

TRAINING FOR PRESCRIBED FIRE JOB ASSIGNMENTS

The various assignments in the prescribed fire management program require different kinds training and knowledge. The training consists of two types:

1. Class and field seminars in fire ecology, fire behavior and fire impacts, and in the planning and execution of prescribed burns.

2. Field application of burning techniques during actual prescribed burning operations in various vegetation and fuel types.

Training Levels

Training has been divided into three levels according to the function and type of responsibility of personnel at the different administrative levels of the department (table 1). These are described for each level as follows:

Level I.--This is provided primarily for personnel at Sacramento headquarters, but personnel at other levels in the department may be included. It requires 22 days of training, including class and field.

Level II.--This is provided for regional personnel in resource management and interpretive assignments (resource ecologists and interpretive specialists), but Sacramento headquarters personnel may be included. It requires 42 days of training, including class and field.

Level III.--This is provided for personnel, either in the State Park Ranger or Maintenance Series at the area level, and requires 72 days of training in class and field. Sacramento headquarters personnel may also enroll.

The 12 days of class and field seminars are the same for all three levels of training. In addition to the general topics indicated in the title, the seminars include departmental fire management policies and programs, reviews of prescribed fire management policies and programs of other agencies, planning aspects, smoke management, monitoring, fuel sampling, fuel models, and the use of computers for fire danger and fire behavior estimations.

The field application of prescribed burning techniques for each level is designed to give each trainee burning experience in different vegetation and fuel types covering different site situations. This is summarized as follows:

	Forest	Chaparral	Grass/herb	Total
	- - - - -	- - - - Days	- - - - -	- - - -
Level I	4	3	3	10
Level II	12	6	12	30
Level III	24	12	24	60

Table 1.--Prescribed fire management training levels and requirements

Training level	Trainee location[1] and job title	Functions in prescribed fire program	Course work required: A — Fire ecology, Fire behavior, Fire impacts	Course work required: B — Techniques of burning, field application	Total
			- - - - - -	Days - - - - -	- - - -
	SACRAMENTO HEADQUARTERS				
I	Forester	Prescribed fire manager (policy, planning and advisory)	12	12	22
	Resource ecologist		12	10	22
	REGIONAL HEADQUARTERS				
II	Resource ecologist	Prescribed fire manager (planning and advisory)	12	30	42
	Regional interpretive specialist	Public information and interpretation	12	30	42
	AREA PERSONNEL				
III	Ranger and/or maintenance personnel	Prescribed burn boss (plan, execute burns)	12	30	42
	Ranger and/or maintenance personnel	Prescribed firing specialist[2]	12	60	72

[1]Positions listed show potential candidates at each location. Selection of trainees is at the discretion of supervisors at each of the headquarters shown.

[2]On small burns, can function as prescribed burn boss also.

Sometime during the 60-day field training, the trainee is required to prepare a project burn plan and to perform as a trainee prescribed burn boss. The trainee must use the planning procedures and format described by Fischer (1978).

The training is for personnel who qualify for the three main prescribed fire positions: fire manager, prescribed burn boss, and prescribed firing specialist. A trainee who completes Level II should be capable of monitoring because the basics of fire monitoring are given during the seminar portion of the training. Also, trainees are assigned as fire monitors during field training. Trainees also serve as crew members during training burns where the duties of a crew member are taught by the instructor.

Of the 40 persons enrolled in the training program since it began in 1980, 9 have completed Level III, 10 have completed Level II, and 7 have completed Level I. The field training progresses slowly because the weather is uncertain and prescription conditions are sometimes elusive.

Our program is still evolving, and we are rethinking some of these requirements. For example, we are considering changing Level III field training requirements from 60 days to 55 days in order to increase emphasis on training in intermediate fire behavior by requiring up to 5 days training in this area.

DEPARTMENTAL CRITERIA FOR SELECTING TRAINESS

Program participants selected from the area level in the program are required to have completed at least the junior year of college work in the biological sciences (preferably in wildland resource management). Area managers may also recommend personnel in the ranger and maintenance classifications for departmental training in prescribed fire management. All personnel assigned to project burning in the field must be in good physical condition.

Regional participants include the resource ecologist, archeologist, and interpretive specialist. Their positions require college degrees in archeology or ecology or in a closely related field such as conservation, forestry, range management, botany, zoology, or wildlife management. Sacramento headquarters participants from the Resource Protection Division should have college degrees in one of the disciplines required for regional participants.

COOPERATING AGENCIES

We received assistance in developing our program from the National Park Service staffs at Yosemite and Sequoia and Kings Canyon National Parks; they provided us with much valuable information for use in our program. Several members of the Yosemite National Park staff have assisted us as instructors in our training program.

Other agencies have also provided information and instructors for our training program. These include the California Department of Forestry, the Forest Service, and the U.S. Department of the Interior, Bureau of Land Management.

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MONITORING AND EVALUATING WILDERNESS PRESCRIBED FIRES

Gardner W. Ferry

ABSTRACT: Monitoring and evaluation activities are critical components to prescribed natural fire programs, and more information about them is needed. Our survey was designed to determine who is collecting data and paying for the collection, how data are being used, and what data deficiencies exist. Monitoring and evaluation activities at the multi-State and interagency level and for smoke management purposes are the most critical concerns. Because smoke does not follow administrative boundaries, managers need to develop a cooperative program that provides a common approach to smoke and air quality monitoring.

INTRODUCTION

If the 1970's can be considered the decade of land use planning, the 1980's can be considered the decade of monitoring. Therefore, the recent attention given to monitoring is not surprising. By whatever title we choose to label an agency's land use planning system, there are universally accepted steps and monitoring and evaluation is one. Monitoring and evaluation are usually listed as the last active steps in a planning system. There is usually a statement that the plan is to be refined or revised as a result of analysis of the monitoring information.

It is important to understand what is meant by monitoring and evaluation, as well as the difference between operational monitoring and research.

Operational monitoring of prescribed fire is the systematic process of collecting and recording data on fuels, topography, weather, air quality, fire behavior, and fire effects to provide a basis for evaluating and adjusting future prescribed fire programs. Evaluation is the process of examining and appraising the results of prescribed fire by using general, qualitative, and quantitative monitoring data. Research can be separated from operational monitoring by the frequency and detail with which data are collected and analyzed and the degree of control exercised over variables.

Paper presented at the Wilderness Fire Symposium, Missoula, Mont., November 15-18, 1983.

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It is not unusual to hear comments, regarding all types of prescribed fires, that too many data are being collected or that the organization has lost sight of operational data needs. As stated in the "Prescribed Fire Monitoring and Evaluation Guide" (Van Wagtendonk and others 1982), operational monitoring is not intended to document prescribed fire variables with the frequency or resolution necessary for scientific research, yet demand for qualitative and quantitative information will likely be viewed as research activities by those not familiar with data collection. The debate will probably never be resolved.

SURVEY REVIEW

To obtain information for this paper, it was necessary to contact those directly involved with ongoing prescribed natural fire programs as well as those in support positions (for example, the support staffs of Boise Interagency Fire Center [BIFC], Regional area and Washington offices). The 25 individuals contacted were selected to provide a cross section of the Western United States and all agencies having experience with natural ignition prescribed fire programs. (Although agencies differed in their approach to lightning-ignited prescribed fires, there was no significant agency difference in how they viewed monitoring and evaluation.)

Questions and summary of survey responses are as follows:

Question 1.--Why do you monitor natural fires, or do you monitor them?

Because all known fire management plans call for monitoring, it was not surprising that all respondents stated monitoring was occurring. Responses to this question are not listed in order of response priority because the type of responses received did not allow a ranking. Generally, the first items listed were most frequently stated as the reasons for monitoring.

1. Safety concerns, to protect life and property.

2. To ensure the fire remains in prescription and inside boundaries.

3. To obtain fire behavior prediction information.

4. To determine if objectives are met.

5. To obtain fire effects information.

6. To anticipate potential problems.

7. Smoke management.

8. To give feedback to the public.

9. To keep line management apprised of activities.

10. To gain information on cost.

The most common reason given for monitoring was to ensure that the fire remained in prescription. The second most frequent response was "to protect life and property." If a prescription is considered to include a margin of safety to protect life and property, the second response could be a restatement of the first.

Several of those responding stated that operational monitoring of prescribed natural fires in wildernesses should have nothing to do with determining whether resource objectives were met. These respondents suggested that such monitoring was inappropriate because prescribed natural fires[1] occur naturally and no value judgment can be made about their impact. Intentionally ignited fires, on the other hand, are intended to reduce fuels and effect certain changes in vegetation (for example, changes in cover, composition, frequency). Therefore, operational monitoring activities for intentionally ignited prescribed fires are designed to determine whether resource management objectives were met.

It is generally true that monitoring natural fires for fire effects is currently conducted for research purposes rather than for operational monitoring, however, natural fires in the wilderness may affect resources (for example, air quality and anadromous fisheries) outside the wilderness. In such cases, monitoring is an operational rather than a research activity. Some respondents suggested such monitoring may facilitate planning for intentionally ignited prescribed fires in wildernesses. When intentionally ignited prescribed burns are used to supplement natural fire programs (as they are in U.S. Department of the Interior agencies), information on natural fires, by terrain and fuel type, can be used to design the burn.

Question 2.--What types of activities are involved with this monitoring (the individual fire and the program)?

All respondents discussed individual fire-monitoring activities a listing of which follows:

[1]Editors' note: please refer to the Foreword for comments on prescribed fire terminology.

1. Size.

2. Fire behavior (spotting, crowning, torching, rate of spread).

3. Weather (temperature, relative humidity, precipitation, windspeed and direction).

4. Fuel moisture.

5. Direction of travel of fire front.

6. Location of the fire, especially regarding special concerns.

7. Topography.

8. Fuel type (by stylized model).

9. Smoke plume direction.

10. Public opinion.

11. Fire effects (water quality, air quality, habitat and population dynamic studies on wildlife).

The monitoring activities involved depended on management's view of the role of monitoring. If monitoring is used to collect data to determine if the fire will remain in prescription and be allowed to continue, then only information necessary to make fire behavior predictions will be collected. If management views monitoring in a more encompassing scope (for example, to gain information in free-burning long duration fires), information on a variety of aspects will also be collected.

The responses fell into two groups: those concerning short-term monitoring and those concerning long-term monitoring. Those questioned were actively involved with short-term monitoring activities (items 1 through 9). Some respondents referred to short-term monitoring as operational monitoring. Long-term monitoring activities were associated with fire effects and social interest.

Most respondents indicated short-term monitoring activities varied with the complexity of the situation. The first stage of monitoring usually involved aerial surveillance. As the complexity of the situation increased (for example, as the size and number of fires and danger rating increased), monitoring shifted to on-site activities. Off-site monitoring activities, such as sampling public opinion, were also mentioned.

Several individuals had stopped monitoring fire effects, especially vegetative fire effects of natural prescribed fires, but had increased monitoring of the effects on their intentionally ignited prescribed burns. The recognition that studies of fire effects must also include information on fire intensity is leading most managers to only expend time on monitoring burns where plots, both in burned and unburned areas, can be

designated before passage of the fire. As discussed in the "Prescribed Fire Monitoring and Evaluation Guide" (Van Wagtendonk and others 1982), monitoring data should be collected from these plots for prefire, fire, and postfire periods. It is critical that information about the fire be collected as it passes over designated plots. Some respondents felt that past observations of flame length and rate of spread were taken randomly at convenient locations. These data were then used to characterize the fire at a specific transect or plot location where vegetation was monitored, regardless of possible differences in fuels and topography.

No responses were received about monitoring activities that addressed the program from a regional or interagency perspective; however, U.S. Department of the Interior, National Park Service, and the U.S. Department of Agriculture, Forest Service, are reporting natural prescribed fire starts to BIFC so they can be incorporated into the daily situation report. Not having this perspective is addressed later as a monitoring and evaluation deficiency.

Question 3.--Do you consider the cost of monitoring a fire management cost or related to a benefiting activity?

All responses indicated fire management funds were used for all or most monitoring. Depending on what is being monitored, many respondents felt that in the future costs will be shared with other resource management activities, such as wildlife, recreation (wilderness) management, and air quality. Aerial surveillance to determine if the fire is in prescription was generally cited as a fire management cost; the Forest Service Northern Region is presently sharing cost with resource activities and fire management. In some situations, the National Park Service has considered such monitoring a suppression cost. Several management units are currently analyzing their activities to see if the cost of monitoring is less expensive than the cost of suppressing the fire with initial attack forces.

Question 4.--Do you monitor visibility, smoke intrusions in sensitive areas, or air quality?

Monitoring of these fire impacts ranged from intensive sampling of particulates and visibility to no monitoring at all. The majority reported that they only plot the direction of the plume during aerial surveillance. The responses indicated the National Park Service to be the agency most involved with air quality monitoring.

Several survey responses indicated more monitoring is needed in this area, but no specific activities appear to be planned. Others indicated that no problems with smoke have occurred to date and that none are anticipated because the areas are remote and because fires were burning at times when maximum mixing in the air occurs.

A few indicated that their management plans were flexible enough to accommodate new situations. For example, if smoke is flowing into a valley from existing natural fires, all new starts may be suppressed, even though the new starts are in a different airshed and do not contribute to the valley's smoke problem. Line managers and fire staffs are responsible for taking action to reduce tensions when a catalyst such as smoke antagonizes the public. Having the freedom to stop all new starts allows the manager to go beyond the formal process outlined in a fire plan decision flow chart. Of course, case-by-case decision analysis is only as good as the monitoring activities that determine public attitudes and potential political issues.

Question 5.--Who does your monitoring (what disciplines, contractors, other agencies)?

None of the respondents used contractors to perform any phase of monitoring or indicated plans to use them in the future. All agencies monitored their own fires, even with cooperatively developed interagency activities. Most management units are developing formal training packages for their on-site monitoring personnel. Fire management suppression personnel performed most monitoring activities. The only nonagency personnel identified in monitoring activities were university researchers.

Question 6.--What do you do with your monitoring data?

The most classic statement was: "I don't have the foggiest idea where it goes." Because numerous respondents were involved with operational monitoring (for example, ensuring safety and whether the fire was in prescription), data were reported to be filed with the fire record and summarized in postseason reports. Those that were involved with an array of monitoring activities indicated the data were used to brief line and staff officers; to make reports for the State, Regional, and Washington offices and BIFC personnel; to share with researchers who may evaluate and publish reports based on them; and to inform the media.

There is a trend that the older the natural fire program, the less monitoring occurs for anything other than safety and prescription compliance. A survey comment that summarized several responses was, "We are past the point of justifying prescribed natural fire and are now only ensuring protection of life and property." Some respondents indicated there are files full of monitoring data never utilized and of no interest to the research community.

The questionnaire was not designed to determine whether monitoring was emphasized more than evaluation. I, along with a few of those surveyed, believe there may be more interest in obtaining information than in evaluating it. I do not believe data are being collected for the sake of collecting data, but some data analyses appear to be informal rather than formal and documented.

Question 7.--What would you do that you are not or, conversely, what are you doing that is a waste of time?

None of the respondents regarded any of their activities as unnecessary. All of those surveyed who were involved with minimal operational monitoring programs (for example, ensuring fire was in prescription) felt their efforts were adequate, sensible, practical, and cost efficient. Several responses in this category indicated additional information would constitute "nice to have information" that would fall in the research category. Because of constraints and difficulties inherent in working with wilderness fires, some suggested that monitoring activities requiring significant control, such as fire effects studies, should focus on scheduled ignitions burns. Mutch (1983), however, indicated opportunities to monitor and evaluate unscheduled, free-burning, steady-state, long-duration fires in wildernesses should not be lost. Because their attributes differ from those of planned ignitions, the data cannot be extrapolated from one to the other.

A few respondents identified a need for more emphasis on visibility and air quality, cost plus net value change over time, and monitoring, evaluating, and reporting public opinion.

MONITORING DEFICIENCIES

The survey results provided an opportunity to review monitoring on a national scale. The two key deficiencies were the failure to monitor and evaluate the program at the interagency level and smoke management.

Monitoring And Evaluating The Program As Well As The Fire

Most of those interviewed were sure their ability to monitor and evaluate individual prescribed natural fires is entirely adequate to prevent blowups. Several management units responsible for natural fire programs have added safeguards by coordinating the number of new starts with the number and size of ongoing fires in their management units and with local danger rating severity levels. Successes to date attest to the success of this policy. Those working with natural fire programs at multi-State and interagency levels did not discuss their ability to monitor and evaluate their programs. Davis and Mutch (this proceedings) describe a disaster as a result of the collapse of precautions previously accepted as adequate. I do not feel that increasing prescribed natural fire programs is tantamount to disaster. In fact, numerous authors, including Van Wagtendonk (this proceedings), have shown that without prescribed fire activity, areas will continue to develop fuel loadings that will eventually lead to grave consequences. I am concerned, however, that many aspects of fire management are changing without a clear-cut plan to guide and coordinate the change. Besides anticipated increases in large areas being managed as prescribed natural fire zones, we see dramatic changes in other aspects of fire management programs. For example, several agencies, especially the U.S. Department of the Interior, Bureau of Land Management, are identifying millions of acres as zones of limited suppression. The low resource value at risk and low negative fire effects and dangerous working conditions outweigh the potential management benefits; therefore, the amount of suppression activities in these areas is being reduced. Although the objective of limited suppression is not the same as that of prescribed natural fire, both activities will result in more acres to burn. In addition, all Federal, State, and private land managers are making greater use of prescribed fire in late spring and summer burns. In areas of the country with extensive slash burning programs, there is intense pressure to make smoke management constraints more lenient by increasing the number of burn days. Summer burning has also increased because recently acquired knowledge and skills permit the use of summer burns to meet some objectives. These uncoordinated policy changes, coupled with an undesirable meteorological event, could create a disaster.

The following hypothetical example illustrates the need for program monitoring activities on a large regional and interagency basis:

It is the first week in September 1970, and the past spring and summer burning conditions have been excellent in northern California, Oregon, Washington, Idaho, Montana, and parts of Wyoming, Colorado, Utah, and Nevada. Summer fire suppression activities have been infrequent. Few fires required interagency support. State, Federal, and private land managers have taken advantage of the conditions and worked hard to reduce their prescribed burning backlogs. There has been ample spring moisture for 2 years in a row. The abundance of annuals and forbs has produced rangeland wildfires, several of which have encompassed more than 100,000 acres (≅40 000 ha). Fire danger ratings have not been unusually high, and several hundred prescribed natural fires are burning in wildernesses, parks, and "back country" throughout the Western United States. It is late enough in the summer for some seasonal employees to have returned to school. The local fire weather office issues a forecast that warns of the passage of an upper short wave trough during the next 24 hours. There is not much moisture associated with the trough, and the anticipated increase in the lightning activity level is slight. Winds are expected to increase but not to exceed 20 mi/h (32 km/h). The winds will likely last for 12 to 18 hours.

Wind is the most sensitive element affecting a fire's behavior. Changes of 3 to 5 mi/h (5 to 8 km/h) in windspeeds at eye level, with all other conditions constant, can dramatically affect a fire's flame length and forward rate of spread. When burning conditions are favorable, winds that increase by 10 to 15 mi/h (16 to 24 km/h) and last for the better part of a day always create extreme problems for prescribed burners and fire suppression personnel.

A not uncommon meteorological event such as high winds could produce hundreds of wildfires (mostly prescribed fires, both naturally and intentionally ignited, out of prescription) across the Pacific Northwest and the Intermountain West. Although no individual fire may in itself be a disaster, the overall situation could quickly become one. Local and shared resources would be inadequate to handle a problem of this magnitude.

The object of this paper is not to analyze disasters, but to review the role of monitoring and evaluation as it relates to wilderness prescribed fires. It appears that there is room and need for fire managers at the regional and multi-State levels to further develop interagency program monitoring and evaluation procedures. Managers have a responsibility to look at the sum of all parts of the fire management program and monitor the program as well as the fire. The fire community must be aware at all times of the magnitude of fire management activities. The system of evaluating fire management activities must not be driven only by numbers of suppression actions.

Increasing Emphasis On Smoke Management Monitoring

Although failure to monitor and evaluate fire management programs at a regional level ultimately has more dramatic effects than failure to monitor smoke management, failing to consider smoke impacts is more likely to attract criticism and severely constrain the entire prescribed fire program. Pressure on prescribed fire managers to improve smoke management activities and comply with State implementations plans (SIP's) and local nonattainment area strategies is constantly increasing. Prescribed natural fire programs have not been as affected by the constraints of air quality regulations as have other prescribed fire activities. Smoke management problems produced by wilderness fires have not generally become a political issue. Because the program is relatively small and is based on the concept of natural management, the public has generally accepted its associated smoke impact. Nevertheless, if smoke becomes a long-term problem, particularly in sensitive areas, the issue will become political and those who now favor or are neutral to the program will become opponents. This occurred in Teton National Park's Ouzel Fire in 1974. As with the herbicide issue, once the die of sentiment is cast, no amount of caution will relieve tensions and bring about full acceptance of the program.

In his paper, "Air quality in Wilderness" (this proceedings), Dennis Haddow addresses the difference between smoke impacts in wilderness and those outside the wilderness. He suggests that to gain public acceptance of smoke in the wilderness and to minimize smoke intrusions outside the wilderness, managers will need to acquire additional information through aggressive monitoring programs. It now appears a fine particulate national ambient air quality standard (PM-10) may soon be adopted. If fire managers are to provide input into such standards, they must develop air resource monitoring programs and provide the data. If they do not, others will monitor and evaluate the programs, develop regulations, and inform the public without input from fire management. It may be necessary to place monitoring equipment (Remote Automatic Weather Stations and air quality samplers) in wilderness to provide information on how to manage and how to protect the wilderness.

CONCLUSIONS

The purpose of this paper has been to review the role of monitoring and evaluation of wilderness prescribed fires. There is a need for fire managers at the regional and multi-State levels to further develop interagency program monitoring and evaluation procedures. It is the managers' responsibility to consider the sum of all the parts of fire management programs and to monitor programs as well as fires. Not until all agencies report daily on their complete prescribed fire activities (intentional and natural ignitions) to interagency operations, such as BIFC, will data be available for evaluation. The fire community must be aware at all times of the magnitude of the situation and rationale for fire management activities. The system of evaluating fire management activities must not be driven only by numbers of suppression actions.

In addition, there must be more deliberate evaluation of smoke impacts. Smoke does not follow administrative boundaries, and the public usually does not care who generated the smoke. Therefore, managers need to increase individual monitoring activities and to develop a cooperative program of smoke and air quality monitoring and evaluation.

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EVALUATING PRESCRIBED FIRES

Kevin C. Ryan and Nonan V. Noste

ABSTRACT: A preliminary method for classifying fire severity permits managers to predict fire effects with reasonable accuracy and thus assists them in prescription development. The classification described here consists of a two-dimensional matrix of flame length classes and depth of char classes. Flame length classes are derived from direct observation or are inferred from postburn observations and reconstruction of the fire environment. Depth of char class is derived from postburn observations of the extent to which fuels were burned, particularly on the soil surface. The relationship between fire severity and vegetation response is useful in understanding postfire survival and recovery of vegetation.

INTRODUCTION

Wilderness fire monitors are responsible for providing information that can be used to decide whether a fire is within prescription. They typically collect information on fuel, weather, and fire behavior; map fire perimeters by burning period; and document fire effects. Feedback from wilderness fire monitoring has played a major role in the initial phase of prescription development, which is a basis for wilderness fire management programs.

An evaluation of fire behavior and effects is essential to deciding if a fire meets land management objectives. A practical means for describing fire behavior and the effects of fire on the soil and vegetation is needed in fire management. This paper describes a method currently being developed to classify the ecological severity of a fire. The technique can be applied to grass, shrub, and forested sites and allows the monitor to make inferences about the survival of meristematic plant tissue on the site and thus about postburn succession.

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Fire severity is the effect of the fire on the ecosystem, whether it affects the forest floor, tree canopy, or some other part of the ecosystem (Vierick and Schandelmeier 1980). Fire severity relates to the degree that on-site plants survive a fire or reproduce from on site meristematic tissue such as rhizomes, root crowns, underground stems, and seeds or the extent to which the site is invaded by seed from off-site plants (Lyon and Stickney 1976). Fire severity is also based on the amount and location of organic matter lost by burning, decreases in the protective forest floor, volatilization of nitrogen and other elements, and transformation of less volatile elements to soluble mineral forms (Wells and others 1979).

To characterize fire severity, it is necessary to classify the heat pulse received by above-ground vegetation and the heat pulse down in the soil. The heat pulse-up is directly related to the fire intensity. It can be classified by directly observing flame length, by observing scorch height and calculating flame length, or by calculating flame length from fire behavior prediction models. The heat pulse-down is termed ground char and relates to factors other than intensity, specifically on a classification of postburn soil and fuel features. (The term char is used here in a general sense, not as specifically defined in fuel chemistry). Fire severity is characterized by combining the flame length classes and ground char classes to yield a two-dimensional matrix. Each cell of the fire severity matrix can be used as an index of ecological change and compared to a variety of fire effects. Given similar phenology and vigor we can then hypothesize that similar fires on similar sites will have similar effects.

Part of the difficulty in characterizing fire severity results from an inconsistent use of terminology. Fire intensity has been variously defined as maximum temperature (Smith and James 1978) or the degree of litter consumption (Schier and Campbell 1978). Terms such as "hot" and "cool" burn are common and are usually unquantified. Stark and Steele (1977) used maximum soil surface temperature and degree of forest floor consumption to quantify hot, medium, and light burns. Numerous authors (Tarrant 1956; Bentley and Fenner 1958; Morris 1970; Wells and others 1979) have used visual observation of postburn soil characteristics to classify fire severity.

A recent trend toward a standard definition bases fire intensity (Alexander 1982; Cheney 1981; Rothermel and Deeming 1980) on the relationship between fireline intensity and flame length, a concept developed by Byram (1959). The use of flame length to classify fireline intensity is consistent with this trend.

A common misconception about fire intensity is that a "stand replacement fire"--one that destroys the overstory--represents the most severe disturbance. Although such a fire may destroy more above-ground vegetation, it is not necessarily as destructive of organisms in duff and underlying mineral soil. The crown fire phase of a wildfire involves primarily the combustion of fine fuels. It devastates the overstory but does little damage to subsurface regenerative organisms. Although the supporting surface fire during a crown fire usually causes some subsurface damage, it is the degree of burning in duff and larger fuels that determines the depth of lethal heat penetration into the soil. If the site is deeply charred, many species may be lost from the site, at least temporarily (Rowe 1983; Flinn and Wein 1977). Directly measuring the extent of residual burnout of fuels is not practical; however, postburn observation of char depth can be used to qualitatively describe the long-term burnout of fuels.

APPROACH TO FIRE SEVERITY RATING

Flame Length Classes

It is difficult to measure the length of pulsating flames accurately (Ryan 1981; Johnson 1982); use of flame length classes is more practical. Five flame length classes are sufficient to characterize flame lengths for most purposes (table 1). These five classes are based on two criteria. First, they are observable in the field. As flames become larger, however, observations become less precise. Thus, as flame length increases, class ranges become broader. Second, the classes are designed to predict what flame length makes death from crown scorch highly probable for different-size classes of trees in temperate forests of North America. If flame lengths exceed 12 feet (≅3.7 m), torching and crowning become a problem even for the largest trees.

It is preferable, if possible, to make direct field observations of flame length. This may not be practical for large prescribed or wildfires, particularly in wilderness areas. Because it is difficult to adequately estimate flame lengths on large fires, information collected by the monitoring team may be used with existing models to approximate flame length. If the fuel and environmental conditions prevailing at the time can be reconstructed, flame length can be approximated (Rothermel 1972, 1983; Albini 1976). It is also possible to calculate flame length from observed crown scorch (Albini 1976; Norum 1976) and estimates of temperature and windspeed. Thus, crown scorch is a valuable post-fire observation for assessing fire severity. When reporting fire severity estimates, the method and the inputs used for determining flame length class should be specified.

Table 1.--Flame length classes

Flame length class	Flame length range	Corresponding crown scorch height[1]	Corresponding tree mortality size class[2]	
	Feet (= 0.3048 m)	Feet (= 0.3048 m)		Inches DBH (= 2.54 cm)
1	0-2	0-9	Seedling	<1.0
2	2-4	9-24	Sapling	1.0-4.9
3	4-8	24-64	Poles	5.0-8.9
4	8-12	64-116	Small saw timber	9.0-13.0
5	>12	>116	Large saw timber	>13.0

[1]The range of crown scorch is based on Van Wagner's (1973) equation 10, assuming the flame length range for the class, 77° F (25° C), no wind, and no slope.

[2]Estimated mortality is based on review of the fire damage appraisal literature primarily for ponderosa pine (Pinus ponderosa) and Douglas-fir (Pseudotsuga menziesii) (Dieterich 1979; Wagener 1961; Lynch 1959; Herman 1954; Bevins 1980). Based on height and diameter information for each class, trees of average height and crown ratio are unlikely to survive the scorching they can be expected to experience.

Ground Char Classes

Several authors have classified postburn ground characteristics. Although various terms such as intensity and severity were originally applied to them, the classifications are conceptually similar. We feel that they can be appropriately termed ground char classes. Postburn ground characteristics have been conceptually and quantitatively related to numerous physical and biological effects. After our review of the literature, we developed the class definitions in table 2.

The visual characterization described in table 2 applies to small areas and is appropriate for evaluating fire effects on single plants, groups of plants, and physical soil properties. Wells and others (1979) proposed extending the concept to stands or larger areas on the basis of a sample of small plots as follows:

1. Light ground char

   <2 percent of the area deeply charred
   <15 percent moderately charred
   remaining area lightly charred or unburned

2. Moderate ground char

   <10 percent of the area deeply charred
   >15 percent moderately charred

3. Heavy ground char

   >10 percent of the area deeply charred
   >80 percent moderately or deeply charred
   remaining area lightly charred

This classification of burned area is appropriate for evaluating larger-scale fire effects such as erosion, determining wildfire rehabilitation needs, and documenting effects of wilderness fires.

The flame length classes (table 1) can be combined with the ground char classes (table 2) to yield a fire severity matrix (figure 1). Each cell of the matrix can be used as an index of fire severity and compared to a variety of fire effects.

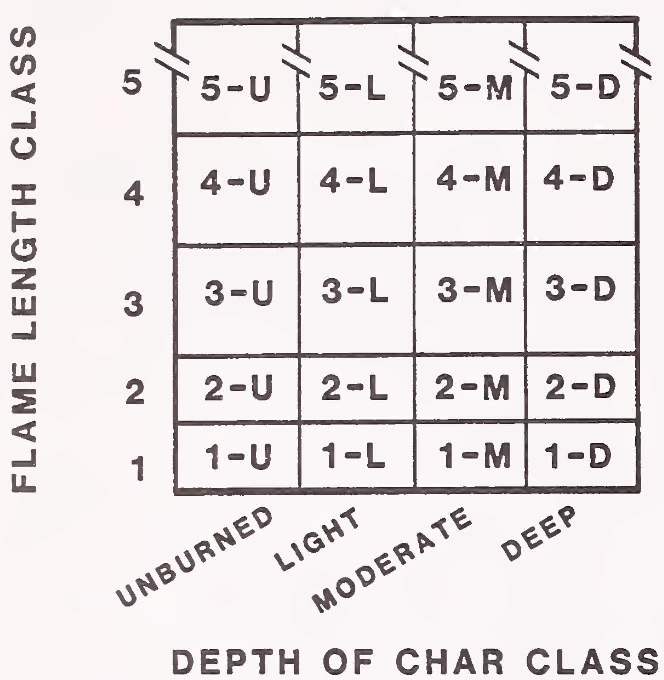

Figure 1.--Two-dimensional fire severity matrix.

Increasing flame length is generally associated with the increasing availability of fine fuels and thus depends primarily on short-term weather conditions. Increasing depth of char depends on the increasing availability of duff, large woody fuels, or both and thus depends significantly on long-term drying.

VEGETATION RESPONSE RELATED TO FIRE SEVERITY

One possible use of a fire severity rating is to determine postfire survival and recovery of vegetation. The morphology and location of regenerating organs are critical to survival. Larger buds, thicker bark, deep rooting, and a high crown base make trees more resistant to damage from a fire. The opposite characteristics predispose a tree to damage. Factors that influence the potential survival of understory vegetation include the type, size, and location of meristematic organs. Generally the deeper, larger, and more extensive the subterranean organs capable of initiating growth, the more likely the individual or species is to survive (McLean 1969; Flinn and Wein 1977; Rowe 1983).

Fires of low flame length and light ground char (1-L) are typical of many early season fires in the Northern Rocky Mountains. These fires should remove relatively few species from a site because many immature and most mature trees can survive them. In the herbaceous and shrub strata several individuals may be top-killed, but those capable of regeneration vegetatively or from stored seed can be expected to survive. The survival of understory species may depend on their phenological state.

Small flame length fires with heavy ground char (1-D) are more typical of late-season backing fires and head fires where dry fine fuels are scarce. These fires can be expected to kill most of the shallow-rooted individuals in the understory and all but the thicker-barked trees. These fires burn considerable duff and can kill much of the seed stored in the forest floor; however, they should have little effect on seed stored in the canopies of trees and larger shrubs. The mineral seedbed and reduced competition favor the establishment of new plants from seed stored in the canopy.

When fine fuels are dry and plentiful and when duff and large fuels are scarce or too wet to burn, fires may be expected to produce high flames and light ground char (5-L). These fires can kill much above-ground vegetation; however, seed stored in the ground and plants capable of vegetative regeneration from subterranean organs are likely to survive these fires.

When fine fuels, duff, and large fuels are plentiful and dry, conditions are suitable for large flame length and deep ground char fires (5-D). Many mid-fire-season wildfires and some slash fires are of this type. These fires remove much of the existing vegetation and seed stored on a site; the aftermath favors light-seeded, highly mobile pioneer species capable of rapidly invading and exploiting an environment where competition has been reduced to a minimum. Nevertheless, Lyon and Stickney (1976) found that after large wildfires, such as Sleeping Child in 1961 and Sundance in 1967, preburn species will make up a large portion of the postburn vegetation. Because fire severity varies within a burn, numerous species can be expected to have viable propagules left on the site. Even in fires classified as severe by the criteria of Wells and others (1979) a considerable portion of the area is not deeply charred.

Between these four extremes is a broad range of fire severity that should produce vegetation responses intermediate to those previously discussed. Noble and Slatyer (1977) and Rowe (1983) have developed conceptual models of plant adaptions to fires; additional work is underway to relate these concepts to fire severity.

Table 2.--Visual character of ground char from observation of depth of burn[1]

Ground char class	Site: Timber/slash	Site: Shrub fields	Site: Grass lands
Unburned	The fire did not burn on the forest floor. Some damage may occur to vegetation due to radiated or convected heat from adjacent areas. Ten to twenty percent of the area within slash burns is commonly unburned.[2] There is a wide range in the percent of unburned area within fires in natural fuels.	See timber/slash	See timber/slash
Light ground char	Leaf litter is charred or consumed. Upper duff may be charred, but the duff layer is not altered over the entire depth. The surface generally appears black immediately after the fire Woody debris is partially burned. Some small twigs and much of the branch wood remain. Logs are scorched or blackened but not charred. Crumbled, rotten wood is scorched to partially burned. Light ground char commonly makes up 0-100 percent of burned areas with natural fuels and 45-75 percent of slash areas.	Leaf litter is charred or consumed, and some leaf structure is still discernible. The surface is predominantly black, although some gray ash may be present immediately after the fire. Gray ash soon becomes inconspicuous. Charring may extend slightly into soil surface where leaf litter is sparse, but the mineral soil is not otherwise altered. Some leaves and small twigs remain on the plants. Burns are irregular and spotty. Less than 60 percent of the brush canopy is commonly consumed.	Litter is charred or consumed, but some plant parts are still discernible. Charring may extend slightly into the soil surface, but the mineral soil is not otherwise altered. Some plant parts may still be standing. Bases of plants are not deeply burned and are still recognizable. Surface is predominantly black immediately after the burn, but this soon becomes inconspicuous. Burns may be spotty to uniform, depending on the continuity of the grass.
Moderate ground char	Litter is consumed.[3] Duff is deeply charred or consumed but the underlying mineral soil is not visibly altered. Light-colored ash prevails immediately after the fire. Woody debris is largely consumed. Some branch wood is present, but no foliage or twigs remain. Logs are deeply charred.	Surface leaf litter is consumed. Some charred litter may remain but is sparse. Charring extends up to 0.5 inches into mineral soil but does not otherwise alter the mineral soil. Gray or white ash is conspicuous immediately after the burn, but this quickly disappears.	Litter is consumed, and the surface is covered with gray or white ash immediately after the burn Ash soon disappears,leaving bare mineral soil. Charring extends slightly into mineral soil, but the soil is not otherwise altered. Plant parts are no longer discernible, no plant parts standing, and the bases of plants are burned to ground level.

continued

See footnotes at end of table.

Table 2.--continued

	Moderate ground char commonly occurs on 0-100 percent of natural burned areas and 10-75 percent on slash burns. Trees with lateral roots in the duff are often left on pedestals or topple. Burned-out stump holes are common.	Some charred stems remain on the plants, and these are generally greater than 0.25-0.50 inches in diameter. Burns are more uniform than in previous classes. Between 40 and 80 percent of the brush canopy is commonly consumed.	Plant bases are obscured in the ash immediately after burning. Burns tend to be uniform. Moderate ground char is generally limited to backing fires and fires burning during dry conditions.
Deep ground char	Litter and duff are completely consumed, and the top layer of mineral soil is visibly altered, often reddish. Structure of the surface soil may be altered. Below the colored zone ½ inch or more of the mineral soil is blackened from organic material that has been charred or deposited by heat conducted downward. Twigs and small branches are completely consumed. Few large branches may remain, but those are deeply charred. Sound logs are deeply charred, and rotten logs are completely consumed. Deep ground char occurs in scattered patches under slash concentrations or where logs or stumps produced prolonged, intense heat. Deep ground char generally covers less than 10 percent of natural and slash areas. One extreme case of 31 percent was reported in a slash burn. In extreme cases, clinkers or fused soil may be present. These are generally restricted to areas where slash was piled.	Leaf litter is completely consumed, leaving a fluffy white ash surface. All organic matter is consumed in the mineral soil to a depth of 0.5-1.0 inches. This is underla by a zone of black organic material. Colloidal structure of the surface mineral soil may be altered. Large branches with main stems are burned, and only stubs greater than 0.5 inches in diameter remain.	Deep ground char is uncommon due to short burnout time of grasses. Surface consists of fluffy white ash immediately after the burn. This soon disappears, leaving bare mineral soil. Charring extends up to 0.5 inches into soil. Soil structure is slightly altered (for consistency with other fuel types, no citations specifically mention soil alteration). Deep ground char is generally limited to situations where heavy loadings on mesic sites have burned under dry conditions and low wind.

[1]Visual characteristics were developed from the following literature sources and combined for consistency: Bever 1954; Tarrant 1956; Dyrness and Youngberg 1957; Bentley and Fenner 1958; Daubenmire 1968; Morris 1970; Ralston and Hatchell 1971; Vogl 1974; and Wells and others 1979.

[2]The area coverage estimates for each of the ground char classes are ranges encountered in the literature and experienced by the authors. Obviously, any combination of depth of char classes is possible. The inclusion of these ranges points out the variability that may be encountered within a given fuel situation.

[3]Some late-season fires have been observed to spread by glowing combustion in the duff, leaving the charred remains of the litter on top of the mineral soil and ash. This should not be confused with light ground char because temperature measurements indicate a considerable heat pulse is received by the mineral soil.

Case Examples

The fire severity rating system has been used to rate fire severity of 22 prescribed slash fires in partial cut stands and of two fires (described below) in the spring of 1983. The Galena Gulch prescribed fire burned May 23, 1983, near Boulder, Mont., and was designed to treat sagebrush and conifer encroachment into natural grass openings and ultimately to improve wildlife habitat. Burning conditions were marginal, and flame lengths were estimated to be 4 to 6 feet in dense patches of sagebrush and conifers. Because the fire did not carry where grass fuels predominated, it produced only a patch burn. The Dismal-October wildfire burned May 30, 1983, near Wallace, Idaho, in a cedar-hemlock stand with heavy dead and down fuels. The fire occurred during a period of high winds and low humidity not commonly encountered at that time of year. Flame lengths were estimated from observations to be 11 feet.

Plots measuring 2.69 ft^2 (0.25 m^2) were placed along a transect and the percentage of each plot meeting the ground char (table 2) was determined. Table 3 shows examples of ground char ratings.

Table 3.--An example of ground char ratings on the Galena and Dismal-October fires

Plot number	Ground char rating: Unburned	Light	Moderate	Deep
	- - - - - - Percent - - - - - - -			
Galena fire[1]				
1	100			
2	60	40		
3	100			
4	40	60		
5	100			
6	10	80	10	
7	10	90		
8	30	70		
9	30	70		
10	30	70		
Average	51	48	1	0
Dismal-October fire [2]				
1			100	
2			100	
3		25	75	
4			100	
5		40	60	
6		100		
7		40	60	
8		85	15	
9		100		
10		100		
Average	0	49	51	0

[1]Grassland criteria applied.

[2]Timber/slash criteria applied.

The Galena Gulch prescribed burn was classified into flame length class 1 based on the average observed flame length. It was classed in the low ground char class. This combination yields a fire severity index of 1-L. Almost all sagebrush and conifers were killed in burned areas, but most bunchgrass survived.

The Dismal-October Fire was classified as 4-M. The mortality rate for all size classes of trees was high. Many of the taller trees, although not completely scorched, were girdled because of cambium heating. Numerous woody and herbaceous understory plants sprouted within 3 weeks of the fire, and many seeds were germinating.

Discussion

A fire severity rating method should possess several attributes. Obviously, any method should be a meaningful index of ecological change and should be broadly applicable. It should be useful for predicting with moderate accuracy a number of fire effects, such as tree mortality and on-site seed survival, and should apply to prescribed fires and wildfires and to many vegetation types. The method should be relatively easy to apply so that it can be used and reported in conjunction with more specific ecological measurements. Its application to wilderness fires especially requires alternatives, such as relying primarily on postfire observations, to minimize the logistical problems of direct observations. Finally, the system should enable managers to evaluate their observations in light of research results. The fire severity classification is an attempt to satisfy these criteria.

Fire severity cannot be interpreted without understanding the burned ecosystem. Stand history, phenology, vigor, and soils must also be considered when interpreting fire severity and effects. For example, if an area burned before a species reached reproductive maturity, this species could be lost from the site. The same species might survive a similar fire at reproductive maturity. Also, if a soil conducts heat relatively well, the soil surface might not be as deeply charred as it might when a soil conducts heat poorly. A lethal heat load, however, might penetrate more deeply in the first instance. In ecosystems having no woody material and little accumulation of organic material on the soil surface, there may be little seasonal variability in depth of char. In such cases the vigor and phenology of understory vegetation may significantly affect the response. In ecosystems where duff accumulates over time, the zone of highest biological activity tends to move upward. Thus, a species that might sprout after a moderate burn in an early successional stage may be lost in a moderate burn in a later successional stage.

The fire severity ratings integrate prefire conditions, fire behavior, and fire effects. Opportunities to evaluate the system with prescribed fires and wildfires provide a basis for improving the classification criteria. Preburn plant survey transects at Galena Gulch were rated using the ground char classification. Transects on the Dismal-October burn were located after the fact, so less is known about the prefire vegetation. Nevertheless, much valuable information can be gained by examining seed germination and vegetative sprouting by ground char classes.

Placing flame lengths into appropriate classes is easier than attempting to define them on a continuum, whether they are based on observations or reconstructions. Classes are easier to observe and should facilitate agreement among observers. Postburn observation of crown scorch is the most practical means of determining flame length classes for rating fire severity. If weather conditions at the time of the fire can be ascertained, flame lengths can be determined from observed crown scorch height for any combination of temperature and windspeed (Albini 1976; Norum 1977). Reconstruction of flame lengths after a fire from fire behavior models is subject to a number of interpretive errors and may therefore not be precise. It nevertheless provides a basis for classification. Despite the lack of precision, the classification should not be off by more than one category.

Because there are few quantitative links between flame length and fire effects, other than crown scorching, more precise definitions appear unwarranted at this time. Managers are able to classify and can therefore use them to document and evaluate fire effects.

Numerous fire effects on soils and vegetation have been related to the criteria similar to depth of char. For example, Tarrant (1956) found that severe burning (equivalent to deep depth char) significantly reduced movement of water into pumice sandy loam and sandy loam clay soils on the H. J. Andrews Experimental Forest in the Cascades of Oregon, while light burning (light depth of char) did not. Other examples are presented in Wells and others (1979) and Miller and others (1974). Fire effects in chaparral (DeBano and others 1979) and in tiaga forests (Vierick and Schandelmeier (1980) have also been related to criteria similar to depth of char. Additional research is needed to define specific plant responses to depth of char.

Other research intended to improve the classification criteria will examine variations among observers in classification, number of plots needed to sample the variation in fire severity on an area, and the relationship between fire behavior and postburn evidence of severity. Operationally oriented questions involve levels of useful information. Can severity ratings be satisfactorily estimated from aerial photographs of low, slow-flying aircraft, or during a reconnaissance walk? Trial use and training sessions will provide opportunities to answer these questions. We also solicit comments from field and research users on the successful or unsuccessful use of the system.

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245 CASE STUDY: THE INDEPENDENCE FIRE, SELWAY-BITTERROOT WILDERNESS

Larry D. Keown

ABSTRACT: The Independence Fire of 1979 in the Selway-Bitterroot Wilderness, Idaho, provides a useful basis for comparing fire management projections with fire management results. The discussion encompasses the fire plan, fire behavior, and fire effects. A detailed evaluation of program results provides a valuable perspective on managing a large, prescribed wilderness fire.

INTRODUCTION

> To protect the wilderness from fire or not--that was the first debate I remembered within the U.S. Forest Service on entering the organization in 1938. The area in question was part of the present Selway-Bitterroot Wilderness . . . . (Fahnestock 1976)

Fire management in wilderness did not become operational, however, until the White Cap Study was initiated in the early 1970's (Aldrich and Mutch 1972). Soon after, fire management plans were written for other drainages throughout the Selway- Bitterroot Wilderness (SBW), and the entire area was covered under a prescribed fire plan by the early 1980's. The Moose Creek Ranger District, Nezperce National Forest, portion of the SBW plan was approved on August 7, 1978; it allowed naturally occurring fires to more fully play their role in the ecology of the SBW.

THE PLAN

The primary objective of the Moose Creek Fire Management Plan (Keown 1978) was to implement that portion of the Wilderness Act of 1964 that states wilderness be:

> managed so as to preserve its natural conditions and which generally appears to have been affected primarily by the forces of nature . . . .

Specifically, the objective is to preserve or enhance the wilderness resource by (1) maintaining vegetative mosaics that are a result of fire, (2) reducing fuels that have accumulated because of past fire protection, (3) maintaining genetic traits that certain vegetation species have developed in response to fire, and (4) maintaining plant/animal interrelationships that have evolved with fire.

The concept of ecological land units (ELU's), developed by Aldrich and Mutch (1972) for the White Cap Fire Management Study Area, facilitates the fire management process. Aldrich and Mutch (1972) described ELU's as:

> recognizable parcels which are ecologically equivalent in terms of their topographic features, vegetation, and fire . . . . Any ELU encompasses some variability, but within an ELU, there are strong and consistent similarities and between ELUs, there are significant and consistent differences.

Ecological land units generate useful information that provides a basis for projecting fire behavior and for making decisions. In addition, fire behavior projections concerning such phenomena as fireline intensity and flame length are useful for contingency planning and predicting certain fire effects. Aldrich and Mutch (1972) described fire behavior for various ELU's in the White Cap plan for the White Cap Fire Management Study Area:

Ecological land unit (ELU)	Fire behavior description
Shrubfield	Community a result of multiple, short-interval, high-intensity fires.
Ponderosa pine savanna	Most flammable ELU; low-intensity fires at 10- to 25-year intervals.
Ponderosa pine/ Douglas-fir South slope	Frequent low-to-moderate intensity fires, mostly confined to the ground or surface, 5- to-50 year intervals.
North slope	High-intensity fires often resulting in stand replacement; fire interval 150-200 years.
Subalpine	Low rates of spread with trees or group of trees torching; spread mostly by spotting; fire interval 100-250 years.
Streambottom	Fire not a frequent event, mostly high-intensity fires burning in conjunction with adjacent ELU's; fire interval 450-800 years.

Paper presented at the Wilderness Fire Symposium, Missoula, Mont., November 15-18, 1983.

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The plan's fire behavior projections were based on Rothermel's (1972) fire spread model, which was developed at the Northern Forest Fire Laboratory Missoula, Mont. Extensive field inventories provided fuel loading values as variables for the model. Fuel and environmental data used to calculate fire behavior predictions are defined in table 1; figure 1 illustrates the rate of spread and fireline intensity generated by these data. Fire management prescriptions for the area once used a hybrid system that combined energy release and ignition components (Keown 1978). This system has since been abandoned in lieu of simpler prescriptions using one index (for example, a burning index or energy release component [Deeming and others 1978]). (For a further treatise of system initially used see Keown [1978; 1980].) The remaining portion of the plan covered such elements as protection of life and property, public education, preattack, monitoring and evaluation, detection, and authorities.

Table 1.--Fuel and environmental data used to predict probable fire behavior predictions by ecological land unit

Ecological land unit	Average slope	Fuel loading	Fuel depth
	Percent	Tons/acre[1]	Feet
Shrubfields	48	Not inventoried[2]	Not inventoried[2]
Ponderosa pine savanna	70	1.8	0.47
Ponderosa pine/ Douglas-fir south slope	58	3.3	.54
North slope	58	3.1	.27
Subalpine	56	3.7	.47
Streambottom	16	2.8	.25

[1]Represents less than 3-inch-sized material.

[2]When the plan was prepared, shrub fuels were not adequately modeled and fuel inventory procedures were not developed.

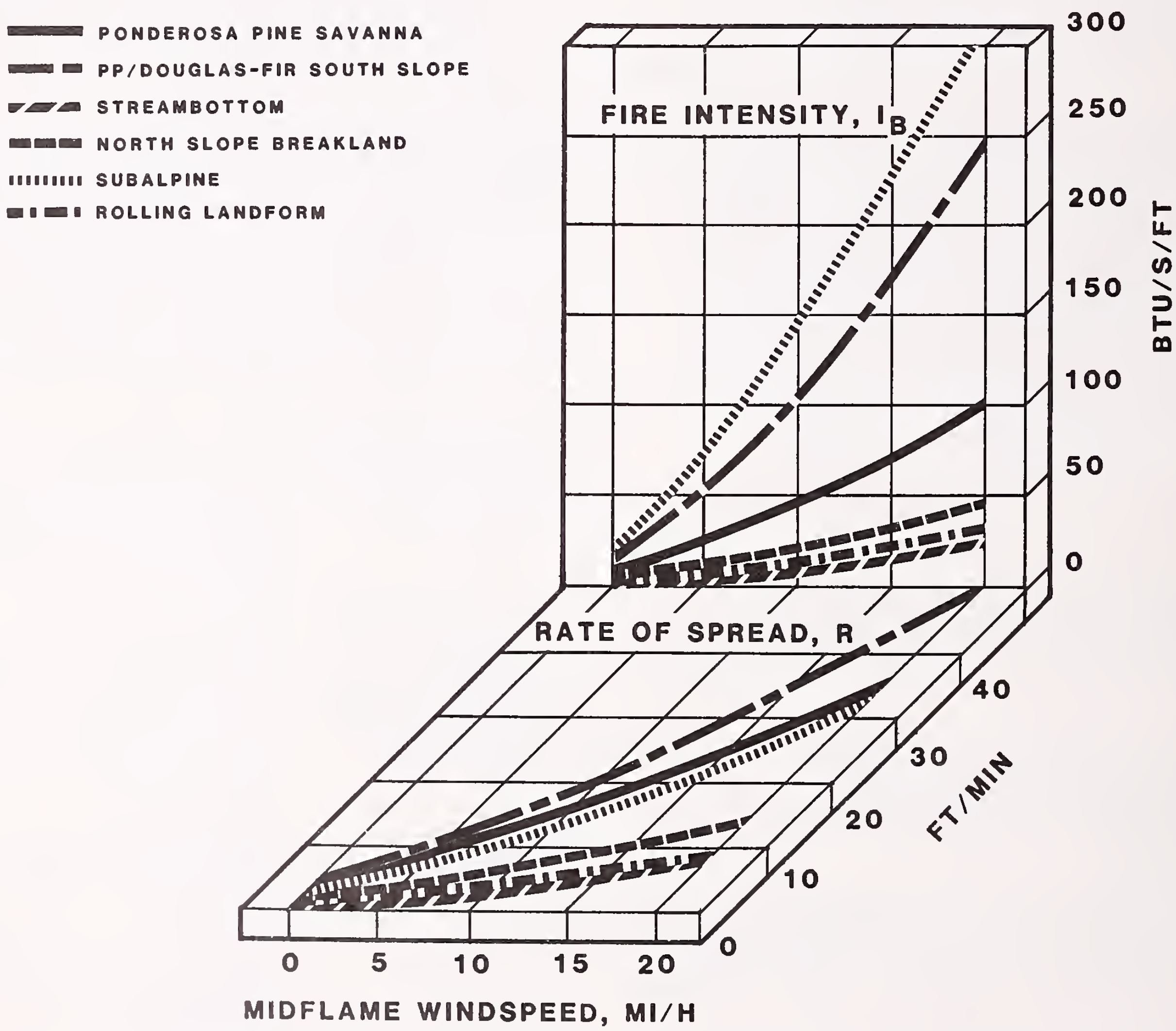

Figure 1.--A comparison of fire behavior characteristics, fireline intensity, and rate of spread by ecological land units.

THE INDEPENDENCE FIRE

During the 1979 fire season, the Moose Creek Ranger District experienced more ignitions than during any year since 1961. Of 59 fires on the district that year, 55 were caused by lightning and four were caused by people. Of the 55 lightning-caused fires, 10 were designated as prescribed fires and allowed to meet management objectives. The most notable of these prescribed fires was Independence (fig. 2), which eventually burned over 16,300 acres (≅6 600 ha) in 106 days.

The Independence Fire tested our ability to manage a wilderness prescribed fire. This early season lightning fire started on July 3 and was discovered by Gardiner Lookout on July 4--hence the name Independence. The Independence Fire grew slowly during July. Most of the acreage burned in the first half of August. Ground personnel monitored the fire from July 10 through early September. Suppression action was required to protect three trail bridges and a private landholding located 7 miles (11 km) southwest and upwind from the fire's point of ignition.

Figure 2a.--The Independence Fire, Selway-Bitterroot Wilderness, 1979. Illustrates typical ground fire in ponderosa pine stand.

Figure 2b.--Independence Fire at height of spread and intensity, early August.

As illustrated, most acreage gains occurred between July 30 and August 12 when fire danger indices began climbing to their maximum values. We divided the fire into four burning periods as follows:

July 3 to July 30.--During this period, the fire burned in a ponderosa pine-covered south slope. Fuels were primarily of the ponderosa pine savanna type, with infrequent patches of Douglas-fir regeneration. Independence moved slowly through this fuel type, backing into the wind for nearly 4 weeks.

July 31 to August 11.--During this period Independence made its most dramatic gains. This is also the period when fire danger indices were rising to maximum levels. The largest gain for any 2-day period was August 4 and 5 when 3,840 acres (≅1 550 ha) burned. Part of this gain resulted from a large burnout operation around Selway Lodge, a private guest ranch. The fire burned through mixed fuel types--backing down dense fir-covered north slopes and then racing up sparse pine-covered south slopes. No large stand replacement fire runs over 300 acres (≅120 ha) were noted. Independence burned on two or three small fronts throughout this period--the entire perimeter never became a major fire front.

August 12 to August 17.--On August 12, rain showers quelled Independence. During this 6-day period, fire spread was limited to 900 acres (≅360 ha). Most of this gain was confined to lighter ponderosa pine fuels on south aspects. Intensities were generally low with minor amounts of crowning.

August 17 to March 1980.--Independence smoldered mostly in duff and heavy fuels during the late summer and fall period. On October 20, the season's first snow fell. An Idaho State Fish and Game employee flying an elk survey over Independence on March 4, 1980, reported the fire still burning in an isolated ponderosa pine snag in spite of the fact that snow covered the entire area.

FIELD OBSERVATIONS, RESULTS, AND EVALUATION

The evaluation of any program requires comparing program results with program planning projections and criteria. The following discussion of the Independence Fire compares fire management results with information from the fire management plan. The Independence Fire provides a useful basis for discussion because of its size, duration, and the variety of fire behavior that occurred.

Figure 3.--Fire perimeter locations of the Independence Fire by 2-day periods. Numbers along perimeter signify month and date. Scale is approximately 1.25 inches per mile.

Monitoring

Ground personnel began monitoring the Independence Fire on July 10. Periodic aerial observations provided general information concerning hot spots, acreage burned, perimeter location, and potential problem areas. Ground monitors concentrated on mapping the forward-moving perimeter; making weather observations; fire behavior observations, specifically flame length and intensity estimates; perimeter mapping; fuels inventory and modeling ahead of the front; and general observations concerning wildlife, fire effects, and burning patterns.

Fire behavior, weather, and perimeter data were radioed to Moose Creek daily. Personnel also calculated fire behavior projections for the next burning period including projected perimeters, flame lengths, and intensities. The location of the fire perimeter was then relayed to the district office by radio using a dot grid mapping system developed on the Moose Creek District. In addition, contingency plans were prepared daily to plan suppression activities if a containment action became necessary. Calculations included the length of line to construct, resistance to control, personnel required, and fire behavior projections.

Fire Behavior

We based fire behavior projections on techniques similar to those reported by Rothermel in 1983. These techniques predict fireline intensity, flame length, and rate of spread. Projections for the Independence Fire used fuel models 8 (short needle conifer), 9 (long needle conifer), and 10 (conifers and heavy fuel loadings) (Albini 1976). Predictions were based on site-specific environmental data such as fuel moisture, wind, and slope. Figure 4 compares predictions to results. Fire behavior predictions were invaluable for planning for limited suppression and contingency actions. In addition, they were used to determine burnout opportunities and when the fire would reach a given point.

Suppression Activities

On July 27, Independence crossed Bear Creek and made an 85-acre (≅34-ha) upslope run. During early strategic planning it was recommended that the fire be confined to the north side of Bear Creek. This action would limit the need for suppression action around Selway Lodge and limit the fire's spread to only two flanks. Thirty-two smokejumpers were dispatched to control the Bear Creek escape.

On July 28, additional forces were ordered to protect the Bear Creek and Pettibone Creek bridges and to continue containing the fire along Bear Creek. The forces were needed to keep the fire from crossing the Selway River. On July 30, the Independence Fire spread onto the Selway River face and crossed the river on August 2. Prevailing up-canyon winds carried the fire toward Selway Lodge located only 1 mile south. A suppression operation intended to protect Selway Lodge began at the property boundary. Firelines were prepared, and on August 4 the crews began a large-scale burnout operation. The entire operation was completed by August 6, and fire crews were demobilized. A skeleton crew remained for mopup and patrol work.

Air Quality

The Independence Fire had little effect on visual air quality until late July. Air quality problems began subtly when inversions each night trapped smoke in the Selway River drainage. The inversion lifted between 1100 and 1200 hrs each day. Most impacts early in the season were onsite; that is, smoke remained generally within the confines of the wilderness boundary. The fire did not develop a convection column until July 30, when the Independence Fire burned into heavier fuels on the north slope of Pettibone Creek.

After July 30, when the Independence Fire burned most of its acreage, visibility problems became very noticeable and severely limited aviation operations at Moose Creek and Shearer airstrips. Problems were compounded when smoke from Independence combined with smoke from the Bearfoot-Peach prescribed fires on the Bitterroot National Forest's portion of the Selway-Bitterroot Wilderness.

The smoke limited the detection of new fires and probably contributed to a higher incidence of wildfires over 10 acres (4 ha).

Vegetation

The responses of vegetation to the Independence Fire were evident as early as mid-August. Hiking upstream along Bear Creek was like traveling through a time machine. Early stages of vegetative development occurred on recently burned sites. On sites that had burned many weeks previously, vegetation was more mature. Most growth followed midsummer showers. Species that responded well initially possessed morphological adaptations that respond well to fire, such as root crowns, caudexes, and rhizomes.

Microsites played an extremely important role in plant responses, particularly in mid-August. The earliest growth occurred on microsites where rocks acted as catch basins for precipitation. A sloping rock would channel water to dormant rhizomes or root crowns, and this moisture stimulated plants to resprout.

Vegetative mosaics were readily apparent on dense, tree-covered north slopes. These mosaics are thought to occur following brief fire runs that burn the crowns of timber stands. The mechanical process involved in creating vegetative mosaics is rather simple. As the fire burns downslope or across slopes, ridges, or small drainages, the topography provides optimal topographic conditions for crowning. The fire then makes a brief run

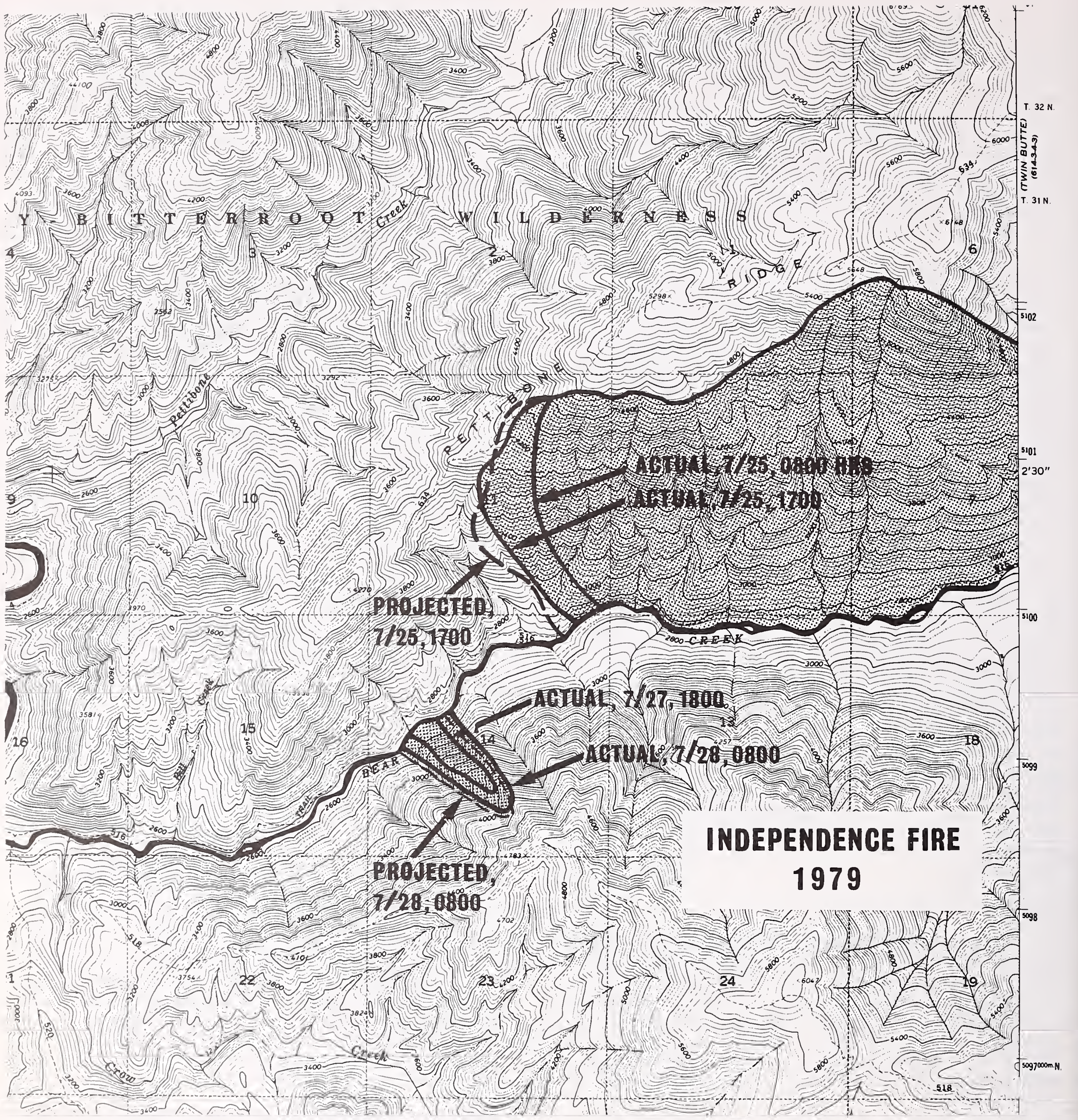

Figure 4.--Fire spread predictions and results of the Independence Fire, Selway-Bitterroot Wilderness.

upslope until fuels or topography change. A small open area, denuded of trees, results. As the fire continues, numerous open areas create a mosaic pattern on the landscape; a pattern that differs from that created by larger stand replacement fires.

Watershed

Baseline data on water quality and sediment samples in salmon spawning gravels were taken while Independence was burning. Future sampling will determine possible effects of fire on the Bear Creek watershed.

On August 23, a localized, short-duration, high-intensity storm--likely to happen only once in 100 years--occurred on several unnamed tributaries of Pettibone Creek. Major washouts carried tons of debris and silt into the creek. Investigations by the Nezperce National Forest soil scientists (Sexton 1979) showed that channel bottoms on two tributaries were incised 20 to 25 ft (6 to 8 m) deep and 10 to 20 ft (3 to 6 m) wide. Massive amounts of sediment and debris were deposited at the mouth of both drainages. Piles of trees and boulders 20 ft (6 m) high were found where these drainages entered Pettibone Creek. Sexton concluded that significant erosion would have occurred regardless of the fire, although the magnitude of impacts may have been altered by the fire.

Wildlife

Observations of the effects of fire on wildlife are limited and consist of personal observations. Raptors were observed working the fire's edge apparently seeking rodents that escaped, were killed, or disoriented by the fire. Two hawks were observed for many days during the early stages of the Independence Fire.

Deer, elk, and moose frequented the recently burned areas. Tracks in newly formed ash confirmed the presence of these big game animals.

Wilderness Visitors And Public Response

When asked how the Independence Fire affected them, wilderness visitors responded in a variety of ways--from indifference to great concern. Those visitors that were concerned with the fire often changed their itineraries and traveled elsewhere. Other visitors attempted to travel through the area to observe the fire and its effects. One visitor stated that the fire was merely an obstacle to traverse during his wilderness experience and expressed no real concern or interest.

Guests at Selway Lodge, who observed the Independence Fire from its inception, felt that they had received a bonus from the experience. Other guests, who arrived later in the life of the Independence Fire, were offered a refund by the owner if the fire had degraded their experience. None of these visitors were known to accept the offer.

During the Independence Fire, and up to 3 years later, many newspaper and magazine feature articles discussed fire's natural role and effects and wilderness fire policy. An editorial in one local newspaper stated that the policy and program for the Independence Fire were apparently sound.

Miscellaneous Fire Effects

The Independence Fire produced many interesting side effects. For example, its heat cracked boulders--a process that accelerates the geologic breakdown of parent material. Large logs situated in a dense stand of Douglas-fir burned entirely without scorching adjacent saplings. This happened repeatedly in early July when live fuel moistures were greatest.

Newly fallen scorched needles protected the soil surface from raindrop splash. Ponderosa pine was the largest contributor, and the needle cast created a carpet of litter. This occurred within 2 weeks of the fire's passing.

In many instances, the fire burned under stands of bracken fern and scorched the fronds. By late summer, these fronds collapsed and formed a protective mulch covering the soil surface.

A contrast of colors resulted from the fire's passing. Greens, browns, golds, and black produced an unusual and pleasing color scheme.

"Survival of the fittest" was apparent during the Independence Fire. Many large, green ponderosa pines burned down because of apparent genetic or environmental defects that caused pitch to accumulate at the bole. Most surviving trees were free of such defects.

The role fire plays in maintaining seral stages was also evident. In areas where Douglas-fir once dominated the understory (as a result of fire's absence), an open condition now exists. Ponderosa pine again dominates because of its ability to withstand fire.

CONCLUSIONS

We were very much interested in whether the Moose Creek Fire Management Plan met each of its objectives. Much of the evaluation is subjective, but it does provide management perspective.

Preserving And Enhancing The Wilderness Resource

Did the Independence Fire preserve and enhance the wilderness resource? The answer is both yes and no. Suppression activities did degrade the wilderness because of the noise of motorized equipment used to construct firelines, cut trees, build fire camps, and to burn out. In other respects, however, the effects of the Independence Fire were more positive as shown below.

Maintaining Vegetative Mosaics

The various fire intensities that resulted during the Independence Fire contributed greatly to creating vegetative mosaics. Landscapes throughout the fire area will now represent a variety of age classes.

Reducing Accumulated Fuels

We often think of fuels as downed, woody material that contribute to a fire's spread and pay little attention to ladder fuels that develop because of past fire suppression. In the absence of fire, understory climax species grow in a multistoried manner under seral species and act as a ladder for fire spread. The probability of crowning increases under these conditions. The Independence Fire broke up much of the horizontal and vertical fuel continuity that results from fire's absence. In this respect, Independence did meet the objective; however, in some instances, the downed, woody fuel loading is now greater because of the fire.

Maintaining Genetic Traits

This objective needs further evaluation, but it appears to have been met considering the variety of responses that occurred. Rapid resprouting, a revegetative mechanism, enabled many shrubs, forbs, and grasses to survive. Protective characteristics, such as thick bark, contributed to the survival of may fire resistant trees.

Maintaining Plant-Animal Interrelationships

Because the Independence Fire produced large-scale mosaic patterns and caused succession to regress to earlier stages, management objectives concerning plant-animal relationships were probably met. Browse and forage (which is more productive in seral stands) will probably be higher in quality and quantity; however, additional studies will be required to fully assess this objective.

ACKNOWLEDGEMENTS

It has been 4 years since the Independence Fire, and it is time to acknowledge those involved with the trying and rewarding moments of this experience. The entire program would not have been possible without the commitment, dedication, and love for wilderness of District Ranger Art Seamans. Supervisor Don Biddison and Fire Staff Officer Jim Thompson of the Nezperce National Forest both played key roles in the success of this pioneer endeavor. Fuels and Fire Ecology Staff Officer Jack Puckett of the Northern Region kept the program on track and provided valuable direction. Dave Clarke collected data for many months and made sure that documentation was thorough. Emil Keck, Penny Keck, and Steve Wright all contributed to helping me keep the events and happenings in perspective. Many individuals from the Intermountain Forest and Range Experiment Station, Northern Forest Fire Laboratory; Nezperce National Forest; U.S. Department of Agriculture, Northern Region; Moose Creek Ranger District; and family members also contributed significantly to the success of the program.

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CASE STUDY: THE OUZEL FIRE, ROCKY MOUNTAIN NATIONAL PARK

David B. Butts

ABSTRACT: The Ouzel Fire burned approximately 1,000 acres (≅400 ha) in Rocky Mountain National Park. The management of this prescribed natural fire became a focal point of political activity around the Park and resulted in the removal of the prescribed natural fire program from the Park pending corrective action. Analysis of the fire indicates that there were good as well as bad fire impacts, both on the natural resources of the Park and on the fire management program. The Park is rebuilding the fire management program to meet Park resource needs.

INTRODUCTION

This case study of a fire in Rocky Mountain National Park highlights the characteristics of the fire and the reaction to it. My intent is to offer constructive analysis. Who did what action and when they did it is not nearly as significant as how decisions can be made and what actions can be taken in the future to avoid similar pitfalls of this particular fire.

THE PARK

Rocky Mountain National Park encompasses approximately 410 mi^2 (1 050 km^2) along the crest of the Front Range, about 65 miles (103 km) northwest of Denver, Colo. The elevations within the Park range from approximately 7,800 ft (≅2 400 m) in the vicinity of headquarters to 14,256 ft (≅4 297 m) in Longs Peak, which forms the north edge of Wild Basin.

Vegetation in the Park ranges from the montane forest vegetation of lodgepole pine and Douglas-fir along the lower east side of the Park through lodgepole pine on up into spruce and fir, which extend to approximately 11,000 ft (≅3 300 m) at treeline. Typically, the valley bottoms are lined with streams and associated wet meadows. Above 11,000 ft (≅3 300 m) the Park breaks into sparse alpine vegetation with extensive areas of raw rock and long-term snowfields. The east side of the Park is typically a series of drainages that head above tree line on the crest of the divide and drop off toward the east, draining out of the Park into private lands at the Park boundary. The forest cover, which is predominantly lodgepole pine along the boundary, extends onto the private lands and continues down the valleys.

The Wild Basin portion of Rocky Mountain National Park is a palmate valley with numerous lakes scattered along the cirques at the head of the valley. The boundary with the Roosevelt National Forest forms the south side of Wild Basin; the north edge of Wild Basin is formed by the 14,256-ft (≅4 300 m) Longs Peak, Meeker Peak, and associated mountains to the west. Access to Wild Basin is only by trail from the short road into the Park from the adjacent community of Allenspark.

THE PLAN

Rocky Mountain National Park operated under a full suppression fire control plan for many years. In 1973 a plan identified fire management units in the Park for the first time. They placed most of the Park within units which incorporated prescribed natural fire[1] (U.S. Department of the Interior 1973). Prescriptions were based on the five manning classes of the National Fire-Danger Rating System, which indicated appropriate action in each of those zones. The options were observation, observation and suppression, and suppression.

The next year, 1974, the plan was rewritten, using considerably different criteria (U.S. Department of the Interior 1974). The prescribed natural fire unit was redrawn with an altitudinal line at 10,000 ft (3 000 m), similar to that at Sequoia and Kings Canyon National Parks. In addition, the prescription criteria calling for suppression of all fires during manning classes 3, 4, and 5 were deleted. This plan persisted through 1978, when the Ouzel Fire took place. As is typical of Rocky Mountain National Park, those intervening years were marked by relatively low fire occurrence and no severe fires.

The responsibilities for implementing the fire management program of the Park rest with district rangers, as do all visitor and resource emergency activities in the Park.

Paper presented at the Wilderness Fire Symposium, Missoula, Mont., November 15-18, 1983.

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[1]Editor's note: Please refer to the Foreword for comments on prescribed fire terminology.

THE FIRE SEASON

Rocky Mountain National Park typically experiences a May to October fire season. In a given year, this could shift significantly, depending upon spring or fall moisture, but as a general rule the May to October period encompasses most fire potential. The convection-generated lightning storms occur more frequently from June to August. In open winters, when little snowfall occurs, the cured grasses of the meadow and montane forest could easily carry fire 12 months a year.

During the fall, winter, and spring, the Park is subjected to moderate to strong westerly winds. The crest of the Rockies runs north and south through the Park, so these winds are downslope winds along the east side of the Park, with their associated warming and drying effect.

During wind velocity studies in Rocky Mountain National Park, David Glidden determined that wind velocities as high as 80 mi/h (129 km/h) occurred within 12 ft (≅4 m) of the rooftop of the headquarters building in Estes Park (Glidden 1974). Two significant blowdowns of trees have occurred on the east side of the Park as a result of unusually violent winds. One of these took place in November and the other in May. The act of judging the transition from the winter high-velocity wind pattern to a summer convectional pattern and the transition from convection behavior back to the higher velocity westerlies is a crucial influence on fire management at Rocky Mountain National Park.

THE FIRE

The Ouzel Fire is thought to have begun with a lightning storm about August 9, at about 10,000 ft (≅3 000 m) elevation in Wild Basin. Based on Park fire records, this would make it the second lightning-caused fire to take place in the Wild Basin area since records have been kept on a regular basis in 1930. Obviously, lightning fires are not frequent in this area; hence each is ecologically of major significance. This fire was detected on August 15 after considerable checking of the general area because of the smell of smoke. Its behavior changed little over the next 10 days. About August 23 the fire began to move to the east, creeping across the floor of the spruce-fir forest. Some trees were burned out and began to fall, so the Park closed the area to the public. This creeping behavior pattern continued until September 1.

On September 1, the fire became much more active. Until that point, the fire had been of interest only to Rocky Mountain National Park staff; however, the behavior of the fire on September 1 and 2, Labor Day weekend, made it a focal point for residents in the Wild Basin area adjacent to Allenspark on the east side of the Park and residents of Grand Lake on the west side of the Park. The key factor was wind. On September 1 the fire was generating a column of smoke to about 15,000 or 16,000 ft (≅4 500 to 4 800 m). By around noon westerly winds had flattened out the column and ashes were being dropped on the Wild Basin Lodge, which is adjacent to the Park boundary. Local residents objected to the threat from the fire, and Allenspark citizens became increasingly vocal about the fire and its potential consequences to their community. The Boulder County Sheriff's Office also inquired about the fire.

Limited suppression actions were taken on the east flanks of the fire at that time; however, the fire was not extinguished. This situation persisted for approximately 2 more weeks, during which time some hotspotting took place by Park crews. Conditions deteriorated significantly, however, on September 15, when winds gusting to 40 mi/h (64 km/h) hit the fire. Those 40- to 50-mi/h winds continued through the night and on through September 16, when the Park fire crew turned the fire over to a U.S. Department of the Interior fire management team. Their suppression action brought the fire officially under control by September 30. The fire was not declared out until December 4; by that time the fire had burned over 1,050 acres (424 ha).

WHAT WENT WRONG

With any fire, some things do not go well; however, these negative aspects are usually useful learning experiences. The Ouzel Fire was no exception. Because this fire was a management fire--a prescribed natural fire in today's terminology--the National Park Service was cited for violating the Clean Air Act. The basis for that citation was the management decisions that had permitted significant volumes of smoke to pour into the nonattainment area that is under the jurisdiction of the Boulder County Health Department.

The prolonged fire, the two periods of smoke and ash deposition outside the Park, and the major run of the fire itself generated considerable public reaction against the Park and its programs. Residents adjacent to extensive areas of continuous forest cover in Wild Basin felt their lives and property had been threatened by this fire, which ran directly at them for several miles. In addition, the community of Grand Lake directly west of the crest of the divide and the Park was subjected to considerable smoke on September 2 in the middle of the Labor Day weekend, which generates considerable income for that small mountain community.

Cooperating agencies--particularly at the county and State levels--felt they had been left out of the decision process and denied participation in activities associated with the Ouzel Fire. Communications were a problem among the various levels of government. This public relations misfortune will persist for many years; however, the most significant loss produced by the Ouzel Fire was the termination of the Park's prescribed fire program. Lightning-caused fires are infrequent at this Park; hence each one significantly influences

the Park's ecosystem, regardless of the acreage involved. As of this meeting, the prescribed fire program is still canceled.

WHAT MIGHT HAVE CHANGED THOSE RESULTS

Like any armchair lawyer, we can invoke 20/20 hindsight and declare what actions would have changed the outcome. Would more training have changed the decisions that were made by the Park staff throughout the life of this fire? Could greater fire behavior knowledge have better prepared the staff to anticipate the realities that developed?

Two errors significantly affected fire management. Forest Service changed the fuel models for the utility weather station that was jointly managed by the U.S. Department of the Interior, National Park Service, and the U.S. Department of Agriculture, Forest Service. In addition, the burning indices in the Park's fire plan were based on the 1972 National Fire-Danger Rating System, whereas the station's daily reports were tied to the 1978 revision by the Forest Service. These two errors may have significantly altered the Park's state of preparedness.

On September 1, the shift in fire behavior was a significant warning that conditions were not typical of a summer day but of the fall weather pattern, which is much less predictable and significantly more hazardous. Should the fire have been cut off at that point? I saw the fire behavior indicated by the smoke column, which rose vertically early in the day and later laid over, dumping ashes on Wild Basin Lodge. The conditions were discussed with Park staff and a recommendation made that they call in individuals with higher fire behavior qualifications for assistance. Unfortunately, that advice was not taken. Should the issue have been carried further?

One concern that was emphasized in discussions at the fire review and in the closeout with the fire management team was the reliability of spot weather forecasts in the Wild Basin area. Personnel were particularly critical of the accuracy of the wind forecasts.

The suppression action necessitated by this fire caused significant impacts on the fireline and along the boundary. Although the total acreage covered by the fire was not high, miles of line were put in and snags were felled, leaving stumps and logs that will persist for decades.

WHAT WENT RIGHT

As indicated earlier, all fires have positive and negative aspects, both from the standpoint of the fire itself and from the larger National Park Service perspective. The Ouzel Fire, with operations ranging from approximately 8,000 ft (≅2 400 m) at lower elevations to well over 10,000 ft (≅3 000 m) at the top, proved the usefulness of the Bell 214 helitanker, with its 720-gallon (2 700-ℓ) capacity. In spite of windy conditions and high elevations, this ship was able to make rapid turnarounds from the water source at the lower end and to deliver throughout the fire area at higher elevations. It was a workhorse in the suppression and mopup actions throughout the fire.

The Ouzel Fire had a major impact on Rocky Mountain National Park ecosystems. It was the largest lightning-caused fire to influence Park vegetation since recordkeeping began in the 1930's. Certainly it played a major part in restoring fire to its natural role.

One little-known spinoff of the Ouzel Fire was its influence on the establishment of the Office of Fire Management in the Washington Office in 1979. Without the notoriety caused by the violation of the Clean Air Act and the attention given the fire by the media, there probably would not have been enough drive to generate the normal year fire programming process and fire management program that we are ›w launching.

In looking at what went right, we must also acknowledge that the lark staff, led by Research Biologist Dave Stevens, has since initiated an effort to rebuild the fire program. In March 1983, he invited numerous fire experts and local personnel to discuss this program. He deliberately drew together many individuals who had at one time or another during the fire been near-adversaries. The meeting was productive and has definitely permitted the Park to move toward reinstating the fire management program that Rocky Mountain National Park needs.

CONCLUSIONS

What does it take to run a fire program in a modest park, with wilderness, and with moderate to low natural fire occurrence? First and foremost, it takes a conservative plan; one that plans the constraints necessary to avoid the pitfalls of prolonged drought, extreme fire behavior, and any other factors pertinent to that geographic area.

It also takes persistent management to sustain a prescribed natural fire program--not many people and not a lot of money, but persistence of management attention. In contrast to a prescribed burn which can be scheduled, executed, and declared out in a relatively short time, prescribed natural fires set their own time frames; although managers can set certain constraints, they essentially must operate according to the fire's own schedule. Management must also see to it that knowledgeable personnel are assigned to those parks and that trained replacements are provided when previous staff are transferred.

Patience is also necessary. The probability of major fires occurring during any one person's assignment at such parks is slim. Major fire frequency in Rocky Mountain National Park, based

on the Northfork Fire of 1957 and the Ouzel Fire of 1978, is approximately once a decade. Because major fires are infrequent, however, does not mean the other 9 years do not make significant contributions to the Park's natural fire program. If one message were to be gained from the Ouzel Fire case study, it would be that having such a program is the significant accomplishment, not the number of fires nor the acres burned in any given year. The concept that nature establishes the schedule of manager is one of the most difficult for management to accommodate, but understanding that point is essential to natural area and wilderness fire programs.

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Section 6. Symposium Summary

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VESTAL FIRES AND VIRGIN LANDS: A HISTORICAL PERSPECTIVE ON FIRE AND WILDERNESS

Stephen J. Pyne

ABSTRACT: Contemporary discussion of fire management is dominated by the merger of a wilderness tradition with that of a fire tradition. Wilderness fire management is not just the restoration of a natural process to a natural environment. It involves the merging of one hybrid of nature and culture, fire, with that of another hybrid of nature and culture, wilderness. Because they evolved more or less independently, the conjunction of these two traditions has yielded a thicket of operational dilemmas and intellectual paradoxes. This association will not endure in its present form: there will continue to be fires in wilderness settings that require management, but wilderness fire as a special philosophical concern and as a domineering phase of wildland fire management will pass.

INTRODUCTION

The association of fire and wilderness is at once ancient and modern. Within our solar system the Earth is the great fire plant. Only the Earth combines the essential components of combustion. Jupiter has lightning and the moons of the outer planets possess atmospheres rich in flammable hydrocarbons. But only the Earth contains all essential constituents, the processes needed to mix them, and an environment suitable for their interaction. Lightning no doubt furnished a source of ignition, and may have catalyzed the evolution of life, which in turn provided the other two essentials for combustion: atmospheric oxygen and fuel. As terrestrial life expanded, so did fire. To complement its ignition source, the Earth also has a suppressant, water. The Earth can start fire, sustain fire, and suppress fire. Testimony to the antiquity of fire can be found in the coal-bearing strata of geologic time. There is little argument that fire is fundamental to the natural history of the plant.

Among the millions of species on the planet, only one has assumed control over combustion. The capture of fire by the genus *Homo*, well in advance of the appearance of *Homo sapiens*, would become one of the fundamental events of natural and human history. With the appearance of the genus *Homo*, the geography and natural history of fire changed dramatically. Humans assumed some control over the start, spread, and suppression of fire. They could manipulate fire in new ways and shape the fire environment to new effects. Free-burning fire was removed from areas where it had previously ranged, and was introduced to landscapes not previously burned. Wherever humans went, they would shape the fire regime of the lands they occupied. For some parts of the world, this process has continued for hundreds of thousands of years; for all of the globe, evidence of this process dates from at least the waning of the Pleistocene.

Equally, the acquisition of fire changed the character of the species that controlled it. The possession of fire became a defining trait of humans, and the manipulation of fire, one of the universal foundations of culture. So long as humans persist, they will continue, through their various fire practices--which respond to culture as well as adapt to natural surroundings--to shape their environment. Few biota now exist that predate the presence of human fire practices. Our evolutionary ancestors made a pact with fire. It is an alliance that has profoundly shaped the planet, and it is a relationship that will not be quickly altered by new conceptions of land use or revivals of old moral enthusiasms.

FIRE AND WILDERNESS

It would seem that the association of fire and wildland, even through the medium of human agents, is again ancient. But wilderness is not the same as wildland or nature. It is a distinct idea, a product of the modern socioeconomic order, and an American invention. Modern day wilderness is an intellectual construction, and wilderness sites are cultural artifacts. This makes the question of wilderness fire very recent. In many ways, far from being a restoration of ancient associations, it represents a unique creation, unprecedented in natural and human history.

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There are two great phenomena at issue here--fire and wilderness. Fire and wilderness stand for two powerful ideas, two great experiences, two distinct sets of practices. That ambiguities, paradoxes, even contradictions should appear when these two phenomena are joined is inevitable. No one conceived the wilderness idea with fire specifically in mind. The wilderness idea had other origins, ultimately in the realm of moral philosophy rather than natural philosophy. And it had proponents--special intellectual interest groups--who were not members of the fire establishment (Allin 1982). Not until the passage of the Wilderness Act fixed the evolving concept of wilderness with legal rigor did the status of fire control in wild areas become a serious question. Quickly, however, the contradiction of fire suppression in wilderness areas was replaced by the paradoxes of fire management in those same sites.

From the beginning there has existed a naive view about the association of fire and wilderness. It states that fire is a wholly natural process and wilderness a completely natural environment; that the two are intrinsically compatible, and have been for geologic eons; that the question of fire management is simply to remove the impediments, all anthropogenic, that inhibit their natural interaction. According to this concept, to establish wilderness it is only necessary to remove the human presence, and to promote wilderness fire it is only necessary to abolish the intrusions of human fire practices. Consequently, wilderness fire management only amounts to a process of environmental restoration. This is, in my judgment, a simplistic interpretation and, ultimately, an unmanageable one.

Reality is far more complex. With wilderness fire we are not dealing with a natural process and a natural environment, but with two hybrids of nature and culture. We are not simply putting a natural process back into a natural landscape, but trying to reconcile one hybrid, fire, with another hybrid, wilderness. Neither hybrid is a fixed idea or set of practices. Both have their own histories, and until very recently they did not overlap in ways that demanded attention. That the process of harmonizing the two should be perplexing-- institutionally, intellectually, and operationally--goes without saying. It would be astonishing if the two had been rendered instantly compatible.

In recent years, these two traditions have come together in powerful ways. Each has reshaped the other. Wilderness managers must accept the ancient symbiosis between humanity and fire, and fire managers, the more recent legal and conceptual status of wilderness. What seems to be a simple physical event, a fire burning in a wilderness site, can thus occupy two different cultural worlds--one formed out of a wilderness tradition and the other out of a fire tradition. So compelling has the merger of fire and wilderness become that it is possible to interpret the general history of contemporary fire management policy and programs as a response to it. This in itself is not unprecedented. From time to time fire management in the United States has organized itself around some dominant kind of fire problem. Catalyzed by the association of fire and wilderness, this type of reorganization has apparently occurred again. Call this most recent epoch the era of <u>wilderness fire</u>.

Thus the dilemma of managing fire in wilderness areas, which might have remained a question of technique internal to fire management, has become something larger. It has acquired philosophical, legal, even moral connotations; and as that simple physical event, fire in wilderness, made the transition to a more metaphysical status, wilderness fire, it reformed fire management as a whole. Accordingly, it is possible to discriminate between <u>fire in wilderness</u>, whose identity is a relatively objective question of geography and fire management technique, and <u>wilderness fire</u>, whose meaning has the properties of a philosophical construction and whose character has informed an entire era in the history of wildland fire management.

The impact of wilderness fire, and the era it has shaped, has been ambivalent. On one hand, it has brought an intensity to the problem of fire in wilderness that had never been present before and that compelled fire agencies to rethink the goals of fire management. On the other hand, it has transformed a technical question in fire management into a Gordian knot of philosophy, law, technical expertise, and popular enthusiasms. It is important to recognize that this transfiguration of a fire problem, fire in wilderness, into a problem fire, wilderness fire, is a transient event.

THE WILDERNESS CONCEPT

Wilderness is not a universally recognized concept. It represents the encounter of Old World ideas with New World environments. It has been said that the greatest event in the history of the Old World was its discovery of the New. To be sure, the New World offered an abundance of natural resources whose plundering could enrich Old World coffers. But, equally, its discovery was a dramatic moment in intellectual history. It was as though the world had been remade, as though a second chance were being given to European peoples to start civilization over again.

Our evolving conceptions of wilderness have reflected this historical experience: whatever predated European discovery, no matter how profound the human component, could be considered wilderness. In particular, the American Indian was an indelible part of the natural order of the New World. Perhaps the incredible aspect of this perception is not that Indians were considered natural but that Europeans, as a result of their own definitions, were typed as unnatural. Almost certainly the origins of this perception are religious, reflecting the Christian belief in original sin, the fall of man from his original state of nature. Not mentioned in the Bible, the Indian seemingly escaped the consequences of the Fall; and by the Romantic period, he could be envisioned as occupying a pristine state of precivilization. With regard to Indian fires, the essential division is not between "natural" man and "technological" man, but fallen man and prelapsarian man (Pearce 1965).

The contemporary concept of wilderness is only the latest in a series of great ideas to emerge from the discovery of the New World. The Noble Savage, the Forest Primeval, the Virgin Land--all are ultimately moral parables by which to criticize the decadent civilization of the Old World and to exhort the New World to do better. They represent myths of a past Golden Age of natural and moral stability, relocated from a Mediterranean Eden to the New World wilderness. Such ideas are moral paradigms and literary conventions, not reports on the state of nature (Bury 1932; Smith 1950). Yet no one--least of all someone with aspirations in fire management--should doubt their power. The pen is mightier than the pulaski. Time and again, awakenings of moral sensibilities and religious enthusiasms have been accompanied by revivals and refurbishings of these ideas. Much of the power of the wilderness idea derives from its association with this heritage. These ideas are an inextricable part of our civilization. In some versions they constitute a national creation myth. In the final analysis, none of us would really wish them away.

Other values have been attached to the wilderness idea. That the land possesses information vital to science, that it offers the opportunity to reexperience the awe of Western explorers and the hardihood of pioneers, that it is a part of our landed heritage, the raw stuff out of which or civilization has evolved--all presuppose the values and institutions of an industrial civilization, a Western civilization, and an American civilization. The contemporary concept of wilderness is not intrinsic to natural environments; it was shaped, and continues to be shaped, by the society that defines it. Other societies do not have this conception of wilderness or wilderness preserves unless they have imported the idea and practice from the West, principally the United States. Even Latin America, which also represents the encounter of Old World and New, did not evolve a wilderness ethos and ideology.

Yet by shaping our conception of wilderness, even to the point of fixing it in legal language, these ideas have assumed the status of management goals. What is a state of mind is presented as a state of nature. Almost all of the paradoxes of wilderness fire derive from the fact that these culturally determined visions--together a creation myth--with their source in literary and philosophical traditions, have been mandated into management goals for field and office. There are many ways to preserve a myth, but land management is an especially intractable one.

The problem of accommodating myth with management, moreover, is doubly complicated because we are not dealing with one cultural tradition but two. Modern wilderness ideas have their origins in the humanities, while wilderness management looks to science. The two cultures--one sacred, the other secular--are not easily reconciled (Snow 1964). The humanities deal with moral universes; the sciences, with natural universes. We cannot solve the questions of the one with the data of the other. Their purposes differ no less than their methodologies. The failure to answer scientific questions by humanistic, ethical, or theological methods is matched by the failure to answer moral questions by scientific processes. On their different purposes, one is reminded of a remark by George Bernard Shaw that science was one of the worst forms of knowledge because it was always changing its mind.

In the case of fire, this disparity has led to astonishing paradoxes. Fire is not simply a natural process, even in the New World. From at least the ebbing of the Wisconsin glaciation, no landscape has been spared from anthropogenic fire. No "natural" landscape has existed since the emergence of the Holocene. To remove anthropogenic fire from such landscapes is not to restore a pristine Golden Age of nature, but to fashion an environment which, in all probability, has never before existed.

It has not been my intention to outline the composition and history of the wilderness idea in detail. That has already been done brilliantly by Roderick Nash (1983). My point is to emphasize the cultural foundation of the concept, to reiterate that wilderness is the outcome of positive human activity, not merely the withdrawal of human presence. Only the nature of that presence and the ideas that inspire it change. Recall, for example, the Leopold Report (1963) with its eloquent admonition that the national parks be managed as "vignettes of Primitive America," preserving or recreating the scene that existed when Europeans first arrived. Just what such a scene looked like is not always easy to confirm. One is inevitably reminded of Bertrand Russell's observation that:

> "return to nature" means, in practice, return to those conditions to which the writer in question was accustomed in his youth. (Russell 1929)

WILDERNESS FIRE

The appearance of a wilderness ideology strong enough to dominate land use decisions has had, of course, enormous repercussions for wildland fire management. In one sense, the problem of fire in remote "wilderness" (backcountry) areas had always been around. But in another sense, until wilderness took on specific statutory and ideological meanings, wilderness fire lacked a unique identity. Fires in wilderness sites were no different from any other fires except that they were more difficult to manage because they were more remote. Their geographic location made them inaccessible, while the low value of lands in which they burned made them distant from a market economy. Eventually, however, fires in wilderness sites acquired unique significance and established a kind of hegemony over virtually all aspects of wildland fire management. It is this issue--wilderness fire as a special phase of wildland fire--that provides the raison d'etre for this symposium.

How this came about is a story I have told elsewhere in greater detail, but a few points are worth emphasizing now. Fire came to America from three sources, and it was applied for four purposes. It came from nature, in the form of lightning; from Asia, at the hands of the American Indian ; and from Europe, through a host of immigrants. It was used to support hunting and gathering economies, sedentary and shifting agriculture, and an industrial order. Each required a different set of fire practices, purposes, and techniques that would direct the application and withdrawal of fire. It is the latest of these accommodations, to the industrial revolution, that has defined wildland fire history over the past century.

Industrialization set in motion changes that have utterly transformed our concept of nature and our use of natural resources. Among the resulting ideas relevant to this symposium were industrial forestry and wilderness, and among the significant revisions in land and resource use was a process of reserving forest and range lands that might be termed the counter-reclamation, because it denied access to these areas for traditional agricultural pursuits. Modern fire management in America dates from the time of these reservations, principally the national parks and the Federal and State forest reserves. Only at this time was wildland fire really distinguished from rural fire, and only in the past couple of decades has wilderness fire been segregated as a separate form of wildland fire. It is a matter of singular importance to the history of wildland fire in the United States that the group of professionals who took charge of these lands, principally the forest reserves, were foresters.

Naturally, foresters looked to European precedents for inspiration. The preliminary efforts--from the concept of a timber famine to the establishment of a Bureau of Forestry and a system of forest reserves--can be viewed as a colossal episode of technology transfer from developed countries, notably Germany, to a developing nation, the United States. The transfer of German forestry was only one small part of an astonishing influx of German culture, from philosophy to physics, that had swept over the United States during the 19th century and only faded with World War I (Geotzmann 1973). Many German intellectuals immigrated to the United States, and American students in search of graduate training pilgrimaged to German universities, much as Third World students now flock to American schools. Even the French forestry school at Nancy to which American aspirants like Gifford Pinchot went for instruction was set up by Dieterich Brandis, a German in the service of the British Empire. In general, American foresters found little precedent for their fire problems, but they did leave with the shimmering vision of a carefully maincured, fire-free forest.

An excellent example of what happened is the story of "Bambi." The original book by Felix Salten was set in an Austrian forest preserve dedicated to game. The villains are poachers. There is no hint of a fire that might sweep through the woods. But when the story was relocated to America by Walt Disney Studios, an apocalyptic fire was inserted. It was as unimaginable for an American forest story not to have a fire as it was for a German forest story to include one. Similarly, the need to accommodate fire was the first requirement of American forestry.

Naturally, American foresters sought to establish a new regime by breaking down the traditional fire practices that had characterized the westward settlement. The easiest method was to eliminate anthropogenic fire by excluding settlers (and Indians, now securely on reservations) from specific areas, and to suppress what fires did occur. Not everyone was pleased with the outcome. Not all traditional usage was excluded from the national forests, but without traditional fire practices such usage was often made difficult. Much of industrial logging moved into the West Coast from the South, and it frequently brought with it fire experiences learned from coping with the southern rough. Other intellectuals, unimpressed with the professional credentials of foresters, wanted to promote the "Indian way" of forest management. Most of these groups wanted more fire, controlled underburning, in the woods.

The question of fire management smoldered until 1910, when the light-burning debate in California went public and the famous Big Blowup swept the Northern Rockies. The timing of these fires, as well as the destruction they caused, changed the course of American fire history. Understandably, confronted by hostile critics from without and by fires within, the Forest Service got tough with fire. It was engaged in a great crusade to save the country from a timber famine; its ranks were composed almost wholly of young men; and in an era that urged the "strenuous life," it had a fire in its eye--some would say a fanaticism--not unlike that of many wilderness proponents of the past decades. It was in no mood to compromise. The Weeks Act of 1911 gave it a mandate to expand its land base and to promulgate its fire protection message through State cooperators. The modern wildland fire protection system of the United States was underway.

From the events of 1910 onward it is possible to divide the modern history of wildland fire management into four eras. Each of these eras focused on a particular kind of fire problem, each developed its own intellectual and institutional solutions to this special fire problem, and each sketched appropriate roles for fire control and fire use. Each, that is, established a suitable set of fire practices. Wilderness fire is the most recent phase of this evolution. In one sense, this progression has been continuous. Fire management expanded in range, it intensified in practice, and it amalgamated new techniques as needed. Each era flows readily from the preceding era. In another sense, however, these eras represent fundamental transformations in purpose and practice. Each developed not simply from an internal momentum within fire protection, but in response to other events, often unrelated to fire management and unimaginable before they actually occurred. Superimposing discontinuities on fire history, moreover, accents the critical role of chance events, the influence of personalities, and the connections fire management has with the larger society that sustains it.

Naming these periods according to their problem fires, these four fire eras might be called the frontier fire (1910-29), the backcountry fire (1930-49), the mass fire (1950-69), and the wilderness fire (1970-present). The details regarding each era are unimportant here. I have told the story elsewhere at some length (Pyne 1982). Of special pertinence are some events surrounding wilderness fire--its arrival, its peculiar achievements, and its prospects.

The origins of the wilderness fire era can be traced to a wilderness ideology that has been articulated with increasing clarity and that has, through legislation, rewritten the statutory authority of the Federal land agencies. The wilderness idea was not a metaphysical aberration or a social fad, though elements of each could attach themselves to it. Rather it consolidated old concepts into a weltanschaung for new lands. Herbert Butterfield has observed that the essence of the scientific revolution did not lie in new evidence so much as in a new way of looking at well-known facts, and he likened Galileo to someone who began picking up the other end of the stick (Butterfield 1957).

Something like this happened with wilderness fire. Its revelations were not based so much on new data as a reinterpretation of old data; not the facts but their cultural context--the promulgation of a wilderness ideology--had changed. Translated into legislation, these ideas compelled new concepts and techniques from fire management. Like other catalyzing events in American fire history, the crystallization of a wilderness ideology did not originate from within the ranks of fire management. Instead it challenged the fire establishment. This made accommodation difficult, and it required the identification of suitable traditional concerns that could bridge old practices and new.

THE LEGACY OF WILDERNESS FIRE

The consequences of this accommodation have affected wilderness management and fire management equally. The conundrum of wilderness fire has sharpened our appreciation for the concept of wilderness, particularly its paradoxes and limitations, and it has refined our wilderness management skills. Unlike so many wilderness problems, it could not be solved by limiting human access; on the contrary, it demanded human intervention, though of particular sorts. Unlike other wilderness dilemmas, it could not be shelved indefinitely or tabled for further study. It would not go away. It was not entirely a human technology. It was as effective by being withheld as by being applied. There was simply no neutral position.

Similarly, wilderness fire represented a new phase in the historic symbiosis of humanity and fire. It was a new category of fire, and it compelled new concepts for understanding and new practices for management. Surely fire belonged in wild lands. On that almost everyone could agree. But under what conditions--conceptual and practical both--fire could be encouraged was far more difficult to answer. The problem was not merely to introduce fire into the landscape, but to do so in harmony with the peculiar tenets of the wilderness concept. Most of the intellectual paradoxes and operational quagmires associated with wilderness fire result from approaching the question from the perspective of wilderness.

Viewed from the vantage point of fire, answers seem obvious. Of course fire must be actively managed in these sites; of course prescribed fire of all sorts--underburning and crown fire, scheduled and unscheduled ignitions[1]--must be used. Not to manage fire would almost mean the abdication of a fundamental human attribute, and in practical terms there is no neutral stance possible. The focus has changed from wilderness fire, with its foundation in the wilderness concept, to fire in wilderness, with its roots in fire management.

The accomplishments of the era of wilderness fire have been impressive. It established new norms for fire use and control, and new objectives for fire relative to land management. It inaugurated a massive, decade-long process of fire planning. It led to new fire policies. It reoriented fire research into biological topics and fire effects at large, both ecological and economic. It dramatically expanded fire-related skills. Principally, this meant handling fire in wilderness areas, but by a process of association it expanded into the realm of prescribed burning as well. It compelled a fundamental reclassification of wildland fire into two broad categories, wild and prescribed fire. Its precepts and techniques have become the training ground for the next generation of fire specialists.

Not all of these transformations owe their existence solely to wilderness fire. There are other arguments for reconstituting fire protection, quite independent of fire problems in wilderness, and there were ample reasons to accelerate prescribed fire projects. But wilderness fire gave these long-standing issues a focus and their reformation a moral energy. In some respects, too, these older problems provided a means of entry into the special conundrums posed by wilderness fire.

Historically, a fire protection system in the United States had thrived because it expanded into new, unprotected lands. By the 1970's, however, that expansion was virtually complete. All of the lands in need of protection were by and large protected; in some areas, the level of protection was shockingly intensive. Suppression and presuppression costs spiraled seemingly out of control. Fire protection was hardly alone in experiencing wildly escalating expenditures; government had been a growth industry, and nearly everywhere funding had gotten out of hand. Fire control, however, had its own peculiar mechanism for escalating costs, and it experienced, through the wilderness challenge, a special form of control. In actuality, several processes came together at roughly the same time. Wilderness concerns rewrote the statutory authority of the Federal land agencies. The reality of diminishing returns compelled some forms of administrative consolidation, especially interagency coordination. Reductions in the rate of Federal spending demanded institutional reforms and policy reconsiderations. But it was wilderness fire that provided a common focus.

In the long run the most spectacular achievement of wilderness fire may be its vindication of prescribed burning. If fire could be used for some purposes, like those in wilderness sites, then it could be used for other purposes and in other locations. If fire was essential for wilderness areas, then it could also be good for other, less pristine environments. In a sense, through the medium of fire, the goodness of the wilderness could be brought to other lands. This was the ideological component. Obviously, there were other, practical considerations. There always had been. Fire use had never been abolished during the evolution of modern fire protection, but its potential usage had always been circumscribed by the particular problem fire that characterized the era. Light burning, for example, had been repudiated not because it was worthless, but because it too closely resembled laissez-faire practices of the frontier with their extravagant waste of resources and their hostility to government bureaus. Piling and burning were encouraged, but not broadcast underburning. Every era had found its own range of potential fire use.

It was not until the effects of wilderness fire justified a general conviction that fire was beneficial and necessary in ecosystems that the fervor grew for a general program of prescribed burning. There were practical concerns, like a buildup of fuels in some environments, and there was an accelerated awareness about the potentials for prescribed fire, spearheaded by the Tall Timbers Fire Ecology Conference. But fuels had built up implacably in some areas for decades without leading to the almost universal adoption of prescribed fire as a solution. Similarly, the range of applications for prescribed fire might have slowly expanded, site by site, purpose by purpose, without becoming a generalized solution to fire management problems. Instead prescribed fire became identified with wilderness fire. Consequently, it was not practical issues, like fuels, that led to the fervor for prescribed fire; it was conviction about the value of prescribed fire, inspired by the wilderness ideology, that encouraged a search for legitimate uses. It was as if distributing prescribed fire became a surrogate for distributing wilderness. The reduction of fuels and the maintenance of habitat channeled prescribed fire into areas of traditional concern to foresters, providing a conceptual and operational nexus between old concerns and new goals.

In brief, wilderness fire encouraged the use of fire, just as previous eras had generally discouraged it. Without wilderness fire as an informing problem, prescribed fire would have likely remained a local epiphenomenon, widely used but not widely promulgated as a national program. Something had to propel the idea into larger circulation, to give it a powerful focus

[1] Editors' note: please refer to the Foreword for comments on prescribed fire terminology.

that would permit all forms of fire use to be lumped together under the rubric of prescribed fire and all other manifestations of fire to be labeled wildfire. The idea of wilderness did just that.

But to match its accomplishments, the era of wilderness fire has created an equally impressive array of operational dilemmas and intellectual paradoxes. One does not have to be a Hegelian to see that a kind of dialectic is at work here. At first wilderness fire, like other problem fires, was defined and promoted in terms of the problems it solved; eventually it will be repudiated because of the problems it creates. The issues debated at this symposium did not really exist as public questions when wilderness fire began to challenge the era of mass fire. Wilderness fire could resolve issues that mass fire could not, and nagging doubts about finer points of philosophy, such as the question of Indian burning, were swept aside. As wilderness fire reorganized fire management in general, however, those minor points have become more and more insistent. Now they dominate discussion about fire management.

The dilemmas will not be overcome solely by appeal to technical information. They will not be solved by inventing a new terminology, or by more elaborate definitions, or by shifting the burden of meaning from one intangible philosophical concept to another. The epistemological clarity of "real world" is, after not, no better than that of "natural." It may matter little to a tree whether the fire that burned it had its origin from lightning or from the hands of an American Indian, a research ecologist, an arsonist, or a careless camper. But that fire is not burning in a wholly natural environment. It burns within a cultural environment, too, and the source of the fire does matter to the society that sustains it. One could make the same argument that it hardly matters to a person killed by gunshot who pulled the trigger or why. It matters enormously to society. This is not simply a scientific question; it depends, ultimately, on the values and institutions of the culture within which the event occurs.

The myths are real and are vital to our national identity. The paradoxes associated with wilderness fire are real. They will only be resolved when wilderness fire no longer dominates fire management at large, when pragmatic field operations replace the philosophical debate because the metaphysics no longer matters in the same way. Such problems are not solved in any technical sense; they are simply bypassed. They become academic issues, not live ones.

THE FUTURE OF WILDERNESS FIRE

It may seem perverse, within the context of a symposium dedicated to the general successes of wilderness fire, to speak about the termination of the era. But if the metaphysical issues will only vanish when the era does, then there is a practical as well as a theoretical point to the discussion. Wilderness fire will not endure forever as an informing problem fire. Each of the four phases of fire management outlined previously lasted only about 20 years. And, if one wished to begin wildland fire management with the establishment of the forest reserve system (1891), another epoch could be added precisely 20 years before the era of frontier fire.

Why this periodicity should exist, I cannot say. It is especially puzzling when one considers the many chance events that have shaped American fire history. A partial explanation derives from the circumstances under which the Forest Service was established. It was created virtually overnight as a result of the Transfer Act and it began with a homogeneous population of young men rather than a general distribution of age groups. The 20 year period might correspond to a bureaucratic cycle of generations. Temperamentally, I do not believe in cycles of history, and for present purposes it is enough to ascribe the cycle to chance. My point is that wilderness fire, too, will pass. It does not really matter whether the change comes at 20 years, or 25 years, or 18 years. It will come. There will continue to be fires in wilderness, but wilderness as a metaphysical concern and wilderness fire as an informing problem will give way to other issues. If the periodicity holds, then the era of wilderness fire will expire formally about 1990. If this analysis is correct, we are already on the downhill side of the era.

Ponder for a moment the implications of this conclusion. One is that the philosophical issues that seem so intractable today will become less so as the ideology of wilderness fades from the fire scene. This is not altogether an occasion for rejoicing. It suggests that about 5 to 8 years remain for wilderness managers to work out in practical terms just how to manage fire on their sites. After that, fires will continue, but fire management will no longer possess the philosophical conviction necessary to devote special energies to them. We will then witness fires in wilderness, but not wilderness fire. The techniques of wilderness fire management must be available and, for most areas, already in place for use by that time. Those areas that do not have operational wilderness fire plans by then may never have them. The scope of fire management is far more vast than wilderness fire, or even of wildland fire; the problems and potentials posed by fire will not long be confined to wilderness arenas. It is vital that pragmatic solutions be found, that after the metaphysical energy vanishes there remains a residuum of field techniques and concepts that can cope with fire in wilderness. Fortunately, the techniques of wilderness fire management are well advanced. The future of wilderness fire may look bleak, but the future of fire in wilderness looks excellent.

EXURBAN FIRE

In this scenario it does not matter much what supersedes wilderness fire. But of course simple curiosity compels one to hazard a guess. There are two dangers in any such forecast. One, of course, is that you are laughably wrong. Especially because chance events--all originating outside fire management proper--have so shaped the evolution of fire policy, any future projection is troublesome. The other hazard, more flattering, is that one is believed, that the imagined future becomes a blueprint for action, that the forecast becomes a self-fulfilling prophecy. Still, there is reason to guess, if only to emphasize the ephemerality of wilderness fire.

My suspicion is that the next problem fire will deal with residential developments in wild or rural lands, what I would label exurban fire. This is not really a rural fire problem, though it resembles one in some respects. The population is not engaged in agriculture; the developments are residential and recreational. Nor is it really an urban-wildland interface problem after the Los Angeles model. The encroachment of the megalopolis against true wild lands is relatively slight, though occasionally spectacular; most cities expand at the expense of agricultural land. Rather this encroachment is by an exurban population, searching after ever more remote suburbs. The outmigration from farms to cities ended decades ago in the United States; it persists now in select cities, like Los Angeles, due to immigration, legal and illegal, from rural areas outside the United States. Instead, this is a secondary migration from urban to exurban sites, from industrial core regions to less populated areas. A good many of such areas occur in wildlands, and some abut wilderness.

The expansion is actually twofold, because wilderness, as formally designated, is also being insinuated into less remote sites, many of them once settled or located near settlements. Either way there is a natural point of transition from wilderness fire to exurban fire. The problem is ubiquitous across the United States, but this in itself is no guarantee that it will assume the stature of a problem fire that can, in turn, inform the national fire management effort. There are several candidates, and if history is a guide, one will be selected, in part, on the basis of chance events.

Under such an exurban fire regime the changes would be many. We would witness a revival of suppression and prevention programs. Planning would emphasize county zoning rather than land management principles. Fuels would more likely be treated through fire codes or mechanical devices than through prescribed burning. Engine companies could be more important than smokejumpers, local volunteer fire crews more than interregional suppression crews. The interagency integration of fire resources would extend down to rural areas. Research would explore new fuel complexes, investigate new burning attributes, and test new strategies for suppression. The transformation would not abolish the management of fire in wilderness, but it would demote wilderness fire from the status of a philosophical interrogation to a routine field operation. The moral energy that has sustained much of the quest for wilderness fire would vanish or become merely quaint.

CONCLUSION

At the moment, however, my concern is less with the future than with the past. The association of wilderness and fire--at an intellectual level so readily asserted and at an operational level so intractable--is a great event in our history. It is an idea and a practice that will spread, in modified forms, to all parts of the world that adopt versions of the American concept of wilderness. But we should ponder the uniqueness of this association, not assume its inevitability.

We are a people who represent the contact of Old World civilization with New World nature. The character of that pre-Columbian landscape is problematical, but we have come to call it wilderness. We preserve it because it is part of the raw stuff that has made us a people, a nation, and a culture. All of this is, of course, an American notion. Nature looks different to other peoples. They do not define themselves as a wilderness society. So powerful has the idea become in recent decades in the United States, however, that it has dictated all manner of land use legislation and practices.

Amidst the enthusiasm for wilderness values, we should not forget that there is another value at risk in the question of wilderness fire. That is fire. Our relationship to wilderness may define our character as a civilization, but our relationship to fire has defined our identity as a species. Only recently have we become keepers of the wild; but for all of our existence as a species we have been, and will continue to be, keepers of the flame. Some peoples will preserve wilderness, some will not. But all will manage fire. We cannot completely subordinate fire to the demands of a wilderness ideology, nor should we want to. We ought to remember that fire, as an ecological process and cultural phenomenon, is different from other threats or challenges to wilderness. We cannot simply manage fire to suit our notions of wilderness; we must also mold our concept of wilderness to suit the reality of fire. Obviously, there is an urgent need to reconcile fire and wilderness. But there is a value, too, in keeping them separate. Both, in their own ways, are testimonies to creation myths: wilderness, to our existence as a nation; fire, to our existence as a species. Each will shape our perception of the other.

From the earliest times societies have maintained sacred fires. These were motivated by practical concerns originally, but in time the fires assumed ceremonial identities as well. They became national fires, symbols of the entire people. Perhaps the best known is the vestal fire maintained at Rome by a cadre of priestesses and virgins, a symbol of the Roman State. The role of fire keeper has become a good deal more secular over the centuries, fortunately for all of us no longer identified with a cult of virginity. But the role remains a special trust. Fire managers should see in wilderness fire an opportunity to preserve a distinct kind of fire and set of fire practices. Fire researchers should welcome wilderness fire as a unique laboratory, a chance to study fires that, as utilization intensifies, may vanish elsewhere. Fire historians will recognize in wilderness fire a variety of national fire, an eternal flame to the settlement of the New World, a vestal fire for America's virgin lands.

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Section 7. Banquet Address

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SORRY, BAMBI, BUT MAN MUST ENTER THE FOREST: PERSPECTIVES ON THE OLD WILDERNESS AND THE NEW

Roderick Nash

I appreciate those kind introductory words about *Wilderness and the American Mind*. I agree that it is a good book, but I also think it is an extraordinarily lucky book. I began writing it in the early 1960's. The first edition appeared in 1964, the year of the Wilderness Act. At that time the Sierra Club was a rather cozy group of sherry-drinking Californians numbering perhaps 15,000. As the environmental movement crested and wilderness became a subject of increasing concern, the membership of the Sierra Club increased to its present level of 350,000. I feel very lucky to have caught a part of this wave, and I think the fact of this Symposium and its popularity is another indication of the fact that wilderness and wildland management is an idea whose time is increasingly coming. All we have to do is avoid that ultimate "prescribed burn" called nuclear holocaust.

We have used a lot of big words at this conference, and it is good to be among professionals who share a common language. I recall, though, the first time I spoke in Missoula, 5 years ago, right here in this room. A lady came up to see me after the talk. She was really excited, pleased with what I had said. "Dr. Nash," she began, "I just want to tell you, your talk was superfluous." I staggered for a second and said, "Well, madam, then perhaps you wish me to publish it posthumously." She replied, "Oh, yes, as soon as possible!" But we all know about "posthumous": it's what happens when that 1,000 Btu fire destroys soil.

I have argued that any consideration of wilderness and wilderness management has to begin with some definitions, and what I want to suggest is that wilderness does not exist. At least it doesn't exist in the way that mountains, rivers, rocks, and trees do. Wilderness is what people think about those things. Wilderness is a state of mind. It has more to do with mental than with physical geography. Let me illustrate for a moment. Consider that an individual has hair, eyes, arms, legs, and so forth. We can all agree that those things exist, we can all define them, but whether anyone calls the sum total of those physical objects beautiful or falls in love with them is a subjective matter--a state of mind.

Banquet speech presented at the Wilderness Fire Symposium, Missoula, Mont., November 15-18, 1983.

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Similarly, we can have a collection of biophysical objects: old-growth forest, burned land, and so forth. Whether anybody calls the collection "wilderness" is again a subjective matter.

This definitional problem complicates the task of the wilderness manager. Let's compare two directives. Say that Ed, a GS-7 Forest Service Technician, is told to level a certain piece of land. Ed knows exactly what to do. So do his supervisor and the public. There is a common criterion. People say, "Ed, this side is a little high, but you can work on that tomorrow." They can finally get out one of those things with the bubble in it, what are they called--"levels"--and say, "Ed, you've done it, you're going to be a GS-9 real soon."

But now let's say Ed is put in charge of keeping land wild. His task is much more difficult. There is no consensus whether to construct a trail or not, require a wilderness permit or not, put up a sign, set recreational carrying capacity, let fires burn. As Bruce Kilgore reminds us elsewhere in this Symposium, "naturalness" is no longer really a satisfactory guide because its definition is moot. So poor Ed finds that keeping land wild is a frustrating thing, he endures criticism and he risks demotion to a GS-5!

To give you another illustration of the subjectivity associated with wildland management, it does matter how fires are started. We heard today from Charlie Van Wagner that the wilderness really doesn't care whether a fire is started by helitorch or by Indians or by careless campers or by lightning strikes. In a sense that's true, but I would submit to you that people do care--a great deal. Wilderness, remember, is a feeling, a state of mind. So how a fire starts can be very important.

As a way of dealing with this subjectivity, I have suggested that we abandon the practice of thinking of landscapes as either wilderness or civilization. Figure 1 suggests that way of thinking, but I feel it is much too monolithic an approach to the problem of definition. It fails to recognize that every landscape is perceived to be a composite of wild and civilized qualities. We should, therefore, begin to think in terms of a spectrum of wilderness values. The proper question is not: "Is this place wilderness?" Rather it should be, "To what extent does an individual perceive wilderness qualities in this place?" This allows for subjectivity. It permits an individual to react to a continuum of environmental conditions as that individual's

prior experience, and even his mood at the moment, dictates. The two arrows in figure 2 are meant to represent two individuals exposed to the same environment. The arrow on the left stands for a person who sees the place as about 70 percent wilderness and 30 percent civilization. This could well be the point of view of a visitor from Maryland vacationing in a National Forest in Montana. The right-hand arrow represents someone from, say, the Brooks Range in Alaska. He sees the Montana forest as consisting of 70 percent civilized qualities and only 30 percent wilderness.

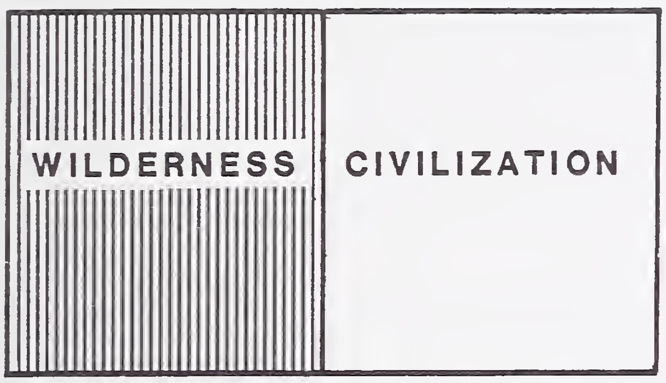

Figure 1.

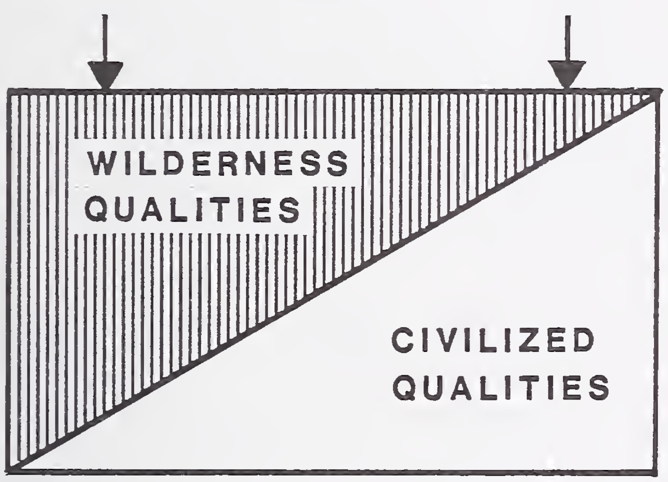

Figure 2.

I believe this scheme, which allows each visitor to read the landscape differently, can help us understand the problem of fire in wilderness. We might ask, does fire move the arrow in figure 2 left or right along the spectrum? I submit that for decades it was assumed that fire lessened the degree of wildness, constituted evidence of civilized humans, and pushed the arrow right. But what I believe we are beginning to discover is that fire in the wilderness ecosystem moves that arrow to the left, makes a place wilder. Twenty years ago 99 people out of 100 would have said, "Fire is evidence that man has destroyed the wilderness." Now there is increasing evidence that fire is appropriate in wilderness. Fire suppression, on the other hand, is an unnatural intrusion of human control.

But we are not completely adrift on the sea of subjectivity when attempting to define "wilderness." There is one general condition that seems to promote the feeling of wilderness in people and that is the concept of the uncontrolled. I have traced one etymology of "wilderness" back to the eighth century to the words "will," which meant uncontrolled. Mobs that pounded at the castle gate were said to be "will." Water that was boiling out of a kettle was uncontrolled, hence "will." Another root runs back to the old English word "deor," a general word for animal. So if you tack the word "deor" onto "will," you get "willdeor," a wild animal as opposed to a dog or cow. Then all you had to do was add "ness" and you had "will deor ness," literally the place of wild beasts.

It is easy to see how herding and agriculture, as they developed about 15,000 years ago, created wilderness. Before this time there was no distinction between wild and civilized environments. Hunting and gathering peoples, who did not domesticate animals or cultivate land, had no concept of wildness. Relevant is the remark of Chief Standing Bear of the Ogalala Sioux, to the effect that the Wild West did not begin until the coming of white man. His people simply saw the land as habitat. A contemporary hunter-and- gatherer has similar difficulties with the concept of wilderness. Through an interpreter, I talked with such an individual a few years ago in Malaysia. I asked him to say his word for wilderness. He came back with things like "green places" or "nature." Finally, in desperation, I asked the interpreter to ask the hunter how he said, "I am lost in the jungle." An exchange occurred, at the conclusion of which the interpreter turned to me, with a smile, and said that the hunter had indicated he did not get lost in the jungle. The question made as little sense to him as would asking one of you how you said, " I am lost in my apartment." Lacking a concept of controlled or uncontrolled nature, the Malaysian had no concept of wilderness. Paradoxically, civilization first created wilderness, then threatened its existence, and finally created the conditions that made for its appreciation.

The idea of the uncontrolled, then, is central to the perception of wilderness qualities. What is "wild" is not restrained, directed, or, to use the term in the 1964 Wilderness Act, "trammeled." (A "trammel," by the way, is a net or shackle designed to catch a bird or fish or control a horse.) Now it follows that if wilderness is the uncontrolled, then wilderness management is a contradiction in terms. "Management" stems from Latin "manus" or hand. So wilderness management is literally laying the hand of man on an environment. When management comes, wilderness goes. Yet everybody in the field now understands that even though wilderness management is a contradiction in terms, some kind of human control is necessary if there is going to be any reasonable illusion of wilderness. We can no longer just draw lines on maps, leave the land alone, sit back, and say, "Now we have preserved

wilderness." That luxury disappeared in the era of Aldo Leopold and Robert Marshall--the 1920's and 1930's. Positive management is now a necessity --although some would call it an unfortunate one.

I want to call your attention at this point to what I think is a useful distinction in thinking about wilderness.

The Old Wilderness.--I have reference here to landscapes and experiences that are for the most part gone in temperate latitudes. We are talking about Lewis and Clark going up the Missouri in 1804, about Jim Bridger at Great Salt Lake in 1824 dipping his hand in the salt water and thinking he had reached an arm of the Pacific Ocean. We're talking about the Old Wilderness when we think of John Wesley Powell putting his boats on the Green River in May of 1869 with a thousand miles of unknown canyon ahead of him. We are talking about John Muir in Yosemite and Bob Marshall in the Brooks Range. We are talking about David Brower making a first ascent every time he climbed a Sierra peak in the 1930's. And if I may add a personal touch, we're talking about my own first raft descent of a river now fighting for its life in California called the Tuolumne. That was only 1970.

The Old Wilderness was characterized by a lack of wilderness management and even a lack of wilderness designation. This was de facto wilderness which Brower once defined as wilderness created by God but not yet recognized by the U.S. Forest Service. The Old Wilderness was just country, poorly mapped and little known. You simply headed out, saddled up, threw on your backpack, launched your boat, or strapped on your skis. In the Old Wilderness maximum-impact camping prevailed. Take a look, for example, at Bob Marshall's journal of his Brooks Range expeditions in the 1930's published as Alaska Wilderness. Marshall and his friends shot everything that moved for food, cut boughs for beds, regularly left fires burning, and buried their tin cans. And this was a guy who really loved wilderness. But for a time it didn't matter much because there were few people out there doing those things. Wilderness designation and wilderness management were unnecessary.

There was also the old way of thinking about wilderness. It was a forest primeval, virgin land, an Edenic place full of murmuring pines and hemlocks, as Longfellow remined us in the poem "Hiawatha." The early forest ecologists spoke of "climax conditions" that every landscape tended toward. There were "good" species and "bad" species. A very anthropocentric way of looking at the ecosystem prevailed.

The Romantic movement in the 19th century and Transcendentalism added to this image of the Old West. Wilderness was a temple full of moral laws, consistently beautiful, singing the praises of the Creator. Landscape painters and, later, landscape photographers developed this image of the American wilderness. Thomas Cole or Albert Bierstadt never painted a burned-over landscape. That did not fit the prevailing romantic image of wilderness. Wilderness was supposed to be godly, moral, pristine, and beautiful; fire scars had no place in Eden. When photography emerged, the same conventions prevailed. Ansel Adams never took pictures of burned stumps. His famous picture of aspen trees near Santa Fe is an example of the "approved" view of wilderness. When smoke filled Yosemite Valley (see Jan van Wagtendonk discussion earlier today), Ansel stayed home and polished his lenses.

The Old Wilderness continued, alive and well, in the coffee-table books that David Brower began publishing for the Sierra Club in 1960. Here was monumentalism carried to the extreme. Sometimes I think of Brower doing for wilderness what Hugh Hefner did for women or, I hastily add, what the publisher of Playgirl does for men. Brower centerfolded wilderness--airbrushed it to perfection. There were no warts, no zits, no unwanted pubic hair. Centerfold models never have headaches at bedtime, and centerfold wilderness is similarly lacking in blisters, mosquitos, and wet sleeping bags. There was, in short, little realism here. But the centerfolds had the advantage of creating an armchair clientele for wilderness with enough political clout to push through, for example, the Alaska National Interest Lands Conservation Act. Still, it is safe to say that a generation grew up thinking that wilderness was something it wasn't and appreciating something that really didn't exist, and this fact created a great many problems for land managers like yourselves. I refer, of course, to problems associated with public opinion concerning fire in wilderness.

From the Old Wilderness perspective, people were the heart of the problem, and fire was something that had to do with people. Let me share with you what I consider the most important document in American cultural history bearing on this matter. In 1942 Walt Disney released an animated film entitled Bambi. Here was the quintessence of the Old Wilderness. Nature was uniformly beautiful. All the animals were happy. Maybe you recall Thumper, the rabbit, and Flower, the skunk. And then, to the sinister strains of organ music, man entered the forest. First, he shot Bambi's mother; and the Great Stag, Bambi's father, comes and says: "Son, you must be brave now because you are on your own." Trauma! Every American kid felt the pangs of loneliness. Next, man returns to the forest and, I am quoting form the captions of a Bambi book on sale today in bookstores, "a hot cinder from Man's campfire spreads and soon the whole forest is aflame." All the happy animals go crazy and the forest, according to Disney's writers, "writhes" in flames. Finally, the fire goes out, man leaves the forest, Bambi finds his girlfriend, Faline, and Old Wilderness conditions return.

Now I submit that this film, Bambi, which was rereleased in 1957 to great public acclaim, did more to shape American attitudes toward fire in wilderness ecosystems than all the scientific papers ever published on the subject. Three lessons were clear: wilderness is good, fire is bad, and man causes fire. It followed that fire must be kept out of the wilderness.

Of course this was accepted wisdom among professional forest managers for many decades too. It was no mere coincidence that the Forest Service used the Bambi characters in a 1944 campaign against forest fire. But Disney got sticky about rights, so the Service commissioned an artist, Albert Staehle, to develop an alternative symbol. Enter in 1945 the bear with pants called Smokey. Two years later came the slogan, "Remember, only you can prevent forest fires." It was an interesting, ambiguous statement that implied, in the public mind at least, that only man caused forest fires and that they had no place in wilderness.

Public recognition of Smokey leaped upward in 1950, when a burned bear cub was found on the Lincoln National Forest in New Mexico. Nursed back to health after the forest fire, little Smokey grew into one of the most potent advertising symbols in American history. The bear became so popular that he received his own zip code from the Postal Service. The ranger hat he wore in the posters gave rise to the association of his name with law enforcement officers in general. I am told that CB radio operators still refer to policemen as "Smokies." But for our purposes, the point is that Smokey joined Bambi in underscoring the idea that fire and Old Wilderness did not mix.

The New Wilderness.-- The New Wilderness refers to a set of conditions, policies, and, most importantly, attitudes that began to take shape in the 1960's and 1970's. The basic assumption is that management is essential if wilderness is to exist. The old days, when you could draw lines around roadless areas and let them alone, are long gone. Permits and quotas to control and eventually limit recreation use came with the New Wilderness. The permit policy began in 1966 in the Boundary Waters Canoe Area. In 1973 the first instances of using permits to restrict visitation occurred in a National Park (Grand Canyon) and a National Forest (San Gorgonio). Now there is a theoretical 10-year wait for a noncommercial permit to float the Colorado River through the Grand Canyon. John Wesley Powell would roll in his grave, but his Old Wilderness will never return. One Forest Service river, the Selway in Idaho, is so tightly controlled that a prospective visitor could wait a lifetime and never get a permit.

Rules and regulations characterize the New Wilderness. There are restrictions against open wood fires, campsites are assigned, length-of-stay is limited, and, the final but necessary indignity, pack-out of human feces is mandated. Bob Marshall would have rolled in his grave too!

Along with the more active management came a new way of thinking about wilderness. It was not uniformly and permanently beautiful. The people who built this new image were poets like Robinson Jeffers on the Big Sur Coast and Joseph Wood Krutch and Edward Abbey on the desert lands of the Southwest. They began to instruct Americans that the real wilderness was tough, often ugly, and loaded with warts. Abbey called it a dangerous and terrible place, but he liked it that way. And this decidedly unromantic view of wilderness contradicted the old Transcendental notion of God smiling from every waterfall at Henry David Thoreau and John Muir. Abbey writes about the time he went to the rim of a mesa to fast for 3 days and ended up seeing God in the form of a pizza pie. But Abbey was appreciating wilderness, not in spite of, but because of its toughness, its occasional ugliness, its incompatibility with the expectations of civilized people.

Fire is acceptable in the New Wilderness; fire is a natural part of the wilderness ecosystem and not just a tragic evidence of man's entrance into the Edenic forest. Fire, according to the tenets of this New Wilderness value system, did not detract from wilderness qualities. In fact, it enhanced them. It was part of the beauty found in the ecosystemic process. Implied here was the idea central to the New Wilderness that wild places are not for everyone, that there was, as George Stankey and John Hendee have reminded us, a wilderness clientele--people who understand and appreciate what it meant to let a landscape be wild. Goodbye centerfolds! Real wilderness sometimes burned. Management of the New Wilderness starts from the assumption that wilderness is not monolithic, that it can mean a variety of things. Baseball, to give an analogy, can be played from Little League up to the majors. Fields, rules, umpires, and management strategy vary widely, but people enjoy baseball at every level.

With this in mind I suggest we quit thinking that there is only one kind of wilderness, one sort of wilderness experience (refer to fig. 1). Remember diversity is inherent in the concept of a recreational opportunity spectrum. I began to propose ideas like this in *Backpacker* magazine in March 1981, arguing the need for a series of wilderness zones based on different kinds of management approaches.

In terms of fire, the New Wilderness concept implies the possibility of diversity. There need not be one fire policy. Why not many? Why not manage different places differently and let the visitor take his choice? If this seems a long way from Old Wilderness, let's accept that. There is no use in pining for its return. The New Wilderness will be all we'll ever have on this planet; and, as Bruce Kilgore implies, it will not be natural anymore. Sorry Bambi, but man must enter the forest. Wilderness management is a necessity and a major determinant of what the visitor will experience; however, the New Wilderness manager might start with the premise that he or she is

part of the problem as well as part of the solution. This recognition is essential if we are to avoid some of the contradictions inherent in that concept of wilderness management. Management should try to be as unobtrusive as possible. We have "uncola"; why not "unmanagers" who are skilled at maintaining those illusions that lie at the heart of the wilderness experience?

There is also the need for public education on the subject of this Symposium. We have to get across the idea that wildfire is one of those uncontrolled factors that define the uncontrolled environment: wilderness. We must teach the paradox that allowing fire to burn, even setting it, is part of the process of enhancing the uncontrolled. We must make clear to the public that, from one perspective, restoring fire to wilderness ecosystems has nothing to do with making them beautiful or creating a so-called "mosaic" of vegetation or maintaining desirable wildfire patterns--desirable, that is, to people. Restoring fire means restoring one of the primary composites of real wilderness.

So let's bring one of those wonderful Forest Service artists from the 1940's out of retirement. We need an anti-image; a new Smokey, perhaps at the controls of a helitorch, setting a prescribed burn and saying in that deep, sad voice: "Only carefully managed fire can really keep wildland wild."

Section 8. Invited Papers

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FIREBASE //

Arlene B. Fields

FIRE INFORMATION

Whether you are a field practitioner, researcher, administrator, educator, or student, doing your job right means being informed. In the rapidly changing field of wildland fire, staying informed can require you to spend unacceptable amounts of time reading journals, reports, proceedings, and hundreds of other new information items each year. On the other hand, staying informed and getting the job done need not be incompatible tasks. Information retrieval systems are available to get you the information you need without unacceptable investments of time and money. FIREBASE is one tool that has proven its ability to help the fire management community keep up with the information explosion.

FIREBASE is a computerized file of wildland-fire-related information. It is a direct response to the need for more rapid and effective delivery of fire information. Simply stated, FIREBASE is a collection of bibliographic citations and, in most cases, digests of documents and other items dealing with wildland fire. The file is kept current by adding new information as it becomes available.

When a user requests information from FIREBASE on a particular subject, a computerized search is made and the items dealing with that subject are automatically retrieved. With a small investment of time, therefore, the user receives an update on the subject.

WHAT FIREBASE INCLUDES

Most of the items cataloged for FIREBASE deal with wildland fire; however, because structural fire is important to wildland fire in areas such as the urban-wildland interface, some structural fire information is also included. FIREBASE is not restricted to items produced in the United States. The data base contains information from dozens of foreign countries including Canada, the U.S.S.R., and Australia.

The following is a list of the broad topic areas covered by FIREBASE:

- Fire and fuel fundamentals, including chemistry and physics
- Experimental fires
- Fire management (general management information)
- Fire management analysis
- Fire management economics
- Fire management planning
- Fire management training
- Wilderness fire management
- Fire prevention
- Fire detection
- Fire suppression, including retardants, equipment, and techniques
- Fire behavior, including case histories
- Smoke
- Fire histories (historical fire occurrence in specific areas)
- Fire effects (ecological aspects of fire and fire damage)
- Fire statistics
- Fire weather
- Fire hazard
- Fire danger indexes
- Fuel management
- Prescribed fires including scheduled ignitions and unscheduled or random ignitions

FIREBASE has approximately 9,000 citations on line. About 50 percent of the items cataloged on FIREBASE have been produced since 1960 about 30 percent of which have been produced since 1970. For historical purposes, however, the file also contains information dating back as far as 1890.

The FIREBASE file contains only bibliographic citations and digests. It should not be confused with systems that store and manipulate raw data. For example, FIREBASE does not contain fire weather data or fire statistics, but it does contain digests of items that deal with fire weather and fire statistics.

If you wish to have a FIREBASE search made, contact the search center that services your geographic location. When you have determined the specific areas of information you need, write (or preferably call) to make the search request.

Paper was invited for inclusion in the Proceedings of the Symposium, Wilderness Fire, by James E. Lotan.

Arlene B. Fields is FIREBASE Program Manager, U.S. Department of Agriculture, Forest Service, Boise Interagency Fire Center, Boise, Idaho.

Make your request as specific as possible; it is helpful, in some cases, if you can identify what you do not want, as well as what you do want. This will eliminated your having to look at references that are only of marginal interest. The response will come in the form of a computer printout listing references to documents pertinent to your request.

At present, there is no charge for a FIREBASE search. As budget and personnel are cutback, FIREBASE's no-cost policy may change. Should this happen, users would be notified of probable charges before a search is made.

SHARING INFORMATION

The FIREBASE system's ability to keep up with the changing laws, policies, and technologies of wildland fire depends on you. There are many more sources of fire information than the FIREBASE input center can monitor. We need your help.

If you have information in any form--published or unpublished--that should be shared with the fire community, send the items to the Boise FIREBASE Operations Center at the address listed below:

FIREBASE Operations Center
U.S. Department of Agriculture
Forest Service
Boise Interagency Fire Center
3905 Vista Avenue
Boise, Idaho 83705

If you would like the items returned to you, please mark your name in a conspicuous place on each item. If the items are already included in the system, they will be returned to you immediately.

Area	FIREBASE Search Centers	Telephone numbers	
		Commercial	FTS
Regions 1 and 4 Idaho, Montana, Nevada, and Utah	Ruth Hyland USDA Forest Service Intermountain Forest and Range Experiment Station 507 25th Street Ogden, UT 84401	(801) 625-5446	586-5446
Regions 2 and 3 Arizona, Colorado, Kansas, Nebraska, New Mexico, North Dakota, South Dakota, Texas, and Wyoming	Bob Dana USDA Forest Service Rocky Mountain Forest and Range Experiment Station 240 West Prospect Fort Collins, CO 80526	(303) 221-1267	323-1267
Region 5 California and Hawaii	Dennis Galvin USDA Forest Service Pacific Southwest Forest and Range Experiment Station P.O. Box 245 Berkeley, CA 94701	(415) 486-3686	449-3686
Region 8 Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, Oklahoma, Puerto Rico, South Carolina, Tennessee, Virgin Islands, and Virginia	Ginger Rutherford Science Library University of Georgia Athens, GA 30602	(404) 542-4535	520-2477
Regions 6, 9, 10 and WO* Alaska, Connecticut, Delaware, District of Columbia, Illinois, Indiana, Iowa, Maine, Maryland, Massachusetts, Michigan, Minnesota, Missouri, New Hampshire, New Jersey, New York, Ohio, Oregon, Pennsylvania, Rhode Island, Vermont, Washington, West Virginia, and Wisconsin.	Dale Burke Forest Resources Library AQ-15 University of Washington Seattle, WA 98195	(206) 543-7484	399-1076

*All Canadian and other foreign requests go to Seattle.

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WILDERNESS FIRE MANAGEMENT TERMINOLOGY

William C. Fischer

INTRODUCTION

Wilderness fire management is a relatively new activity; consequently, universally accepted terminology is lacking. Different terms are often used to identify identical processes. Conversely, identical terms are often used to identify different processes. Definitions are often unrelated to the literal meaning of the terminology. The resulting jargon creates an impediment to effective communication between professionals as well as with the public.

The following discussion attempts to provide a common wilderness fire management terminology. This suggested terminology was developed with one overriding rule: the definition of a term is based on the literal meaning of the words that make up that term. The purpose of this approach is to provide a terminology that is logical and easy to understand.

WILDERNESS FIRE MANAGEMENT

> *Wilderness fire management is the deliberate response to and use of fire through the execution of technically sound plans under specific prescriptions for the purpose of achieving stated wilderness management objectives.*

This definition places no preconditions on the practice of fire management. It is meant to encompass all fire-related plans and actions. Often, wilderness fire management is defined only in terms of reintroducing fire. Reintroduction implies that fire was absent long enough to have become unfamiliar.

The prior absence or successful exclusion of fire is not a requirement for wilderness fire management. Some of the legitimate objectives of wilderness fire management are not necessarily related to the prior occurrence and frequency of fire (see Romme 1980 for definitions of fire history terms). Examples are visitor safety, protection of private property, boundary considerations, endangered species protection, and habitat management. Also, few wildernesses have experienced total fire exclusion for ecologically significant periods of time. Effective fire control has existed for less than 80 years, a time span well within the natural fire-free interval of many wilderness vegetation types. Even the most aggressive fire control programs have had notable failures. Many of the fires that have started during periods of very high and extreme fire danger have escaped initial attack and burned large acreages as fast-spreading, high-intensity, stand-replacing fires. Successful fire control has undoubtedly reduced the acreage burned in many wilderness areas, especially during the past several decades of high-technology fire control. Perhaps the most significant impact of successful fire control has been the nearly total elimination of the easy-to-suppress, slow-spreading, low-intensity surface fire. The vegetative mosaics that resulted over large areas, after such fires periodically flared up, ran, and dropped back to the ground in response to changes in weather, topography, and fuel, are generally considered vital to the ecologic integrity of most wilderness ecosystems.

Wilderness fire management is often defined in terms of naturally fire-dependent ecosystems. *An ecosystem can be called fire dependent if periodic perturbations by fire are essential to the functioning of the system* (Heinselman 1978). It is essential to identify fire-dependent ecosystems and ensure that wilderness fire management plans reflect such situations where they occur. Wilderness fire management plans can, however, be written for ecosystems that are not fire dependent. Wilderness fire management is an appropriate activity in any wilderness where fire occurs. There are legitimate objectives for wilderness fire management other than maintaining fire-dependent ecosystems--for example, the protection from fire of vegetation that is not ecologically dependent on periodic fire.

The foregoing definition of wilderness fire management is a functional definition. It relates to the important tasks associated with the practice of wilderness fire management: responding to fire, using fire, and executing plans to achieve wilderness objectives. Many wilderness management objectives were achieved by the former practice of fire control. What, then, distinguishes wilderness fire management from wilderness fire control?

Paper presented at the Wilderness Fire Symposium, Missoula, Mont., November 15-18, 1983.

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In areas where lands are managed for forest products and prices can be used to evaluate the resource being protected, the distinction is not too difficult to make. Fire management in such cases implies cost effectiveness; that is, the cost of putting a fire out should not exceed the value of the resources being protected. Applying this criterion, however, does not help make the distinction between fire management and fire control for park and wilderness lands. The difference, according to Van Wagner and Methven (1980), is that wilderness fire management implies vegetation management.

It is important to realize that wilderness fire management is in fact vegetation management. It requires, as Van Wagner and Methven (1980) suggest, a vegetation plan that is ecologically compatible with what can be achieved by managing fire, either through its application or its exclusion. Wilderness fire management planners must decide what kind of vegetation and associated wildlife are to be maintained, enhanced, or discouraged in the planning area. Planners must then determine what kinds of fires and fire frequencies will produce the desired vegetation. This is no small task. Nonvegetation-related considerations and constraints usually compromise the ecologically ideal situation. The ideal should, nonetheless, be described as a basis or reference point for wilderness fire management in a given park or wilderness area.

RESPONSE TO FIRE

Wilderness fire management is defined above as the *deliberate response* to and use of fire through the execution of technically sound plans under specific prescriptions for the purpose of achieving stated wilderness management objectives. *A deliberate response to fire is a response that results from careful and thorough consideration of consequences.* It is a planned response. There are three general ways to respond to a fire: ignore it, attack it, or allow it to burn according to a predetermined plan. Ignoring a fire, or just letting it burn, is nonmanagement; hence it is not an acceptable fire management response.

Fire attack can be delayed, aggressive, or modified. *Delayed attack means that attack does not immediately follow discovery.* A fire that is discovered at night, for example, might not be attacked until daylight. Delayed attack, once it occurs, can be aggressive or modified. *Aggressive attack usually follows discovery immediately and with sufficient force to effect control at the earliest possible time with minimum acres burned. Modified attack is less than aggressive attack.* Suppression forces, techniques, strategy, or some combination of these factors are less than those defined for aggressive attack. The "minimum total" concept applies here (U.S. Department of the Interior, Fish and Wildlife Service 1977). For example, additional acres burned might be acceptable if one uses hand tools rather than tractors to build fireline in a wilderness area. Delayed and modified attack, like aggressive attack, should be fast, energetic, thorough, and conducted with regard for personal safety.

Differentiating between delayed, aggressive, and modified attack emphasizes the specific tactics of fire attack. Another approach is to emphasize overall fire attack strategy. Using this approach, three different fire responses are available: confine, contain, and control (U.S. Department of Agriculture, Forest Service 1981). *To confine a fire means to restrict it within boundaries that are either predetermined (preattack planning) or determined during the fire. To contain a fire means to surround it with a fireline, or firelines if spot fires exist, for the purpose of checking the fire's spread. To control a fire means essentially to put it out.* This involves fireline construction, burning out, cooling hot spots, and other actions that remove any threat of subsequent escape.

PRESCRIBED FIRE

The final response to fire is allowing it to burn as a prescribed fire. Allowing a fire to burn according to a predetermined plan is synonymous with the deliberate use of fire because both actions result in a prescribed fire. *A prescribed fire is any fire burning in a predetermined area under predetermined environmental conditions and behaving in a predetermined manner to accomplish a predetermined management objective.* Ignition of a prescribed fire can be scheduled or unscheduled. *A scheduled prescribed fire is one ignited by the manager at a predetermined time. An unscheduled prescribed fire is one that is ignited as a result of an act of God or unauthorized human activity.* The time of such ignition is not known in advance.

The terms "*planned ignitions*" and "*unplanned ignitions*" are used by many fire managers instead of scheduled and unscheduled prescribed fires. A planned ignition is defined as a fire started by a deliberate management action, whereas an unplanned ignition is defined as a fire started at random by natural or human causes. The problem with this terminology is that it implies, for example, that a lightning-caused fire allowed to burn under prescription is unplanned. The fact that a prescription exists, under which the fire is burning, contradicts such an implication. The fire in this example is, in fact, planned (intended, anticipated, expected). The exact time and place of its occurrence are not known in advance, however; hence the fire is unscheduled. A basic premise of this suggested terminology is that all prescribed fires, by definition, are planned.

A prescribed fire can, then, be simply defined as any fire that is burning according to prescription (a prescription is a written direction for the use of a therapeutic or corrective agent). *A fire prescription is, therefore, a written direction for the use of fire to treat a specific piece of land.* The directions contained in a fire prescription consist of predesignated criteria that distinguish a prescribed fire from a wildfire.

WILDFIRE

A wildfire is any fire that is not a prescribed fire. It is an unwanted fire. A prescribed fire that deviates irreversibly from prescribed conditions (escapes prescription and cannot be quickly brought back into prescription) becomes a wildfire (also called an escaped fire, see below). Fires that receive delayed or modified attack are wildfires, not prescribed fires.

Wildfires that cannot be successfully controlled by initial attack forces and prescribed fires that escape prescription and burn as wildfires are called escaped fires. Subsequent action on such fires is based on a plan of action developed as a result of analyzing alternative suppression strategies. An alternative is selected on the basis of total cost effectiveness, public safety, probability of success, protection of property, and the effects of fire and fire suppression on the resources. The results of such *escaped fire analysis* or *situation analysis* are not prescriptions and should not be considered as such. The fire, regardless of management action taken following escaped fire analysis, remains a wildfire.

In the case of an escaped prescribed fire the decision may be to take the limited suppression action necessary to bring the fire back into prescription. If such action is successful, the fire may regain prescribed fire status.

FIRE MANAGEMENT AREA

A fire management area is defined as one or more parcels of land with common fire management objectives (U.S.Department of Agriculture, Forest Service 1978). This term is being used in two ways. In some cases it is used to mean the planning area, for example, the Selway-Bitterroot Wilderness Fire Management Area. In other cases, the term fire management area is used to identify portions of the planning area for which specific fire management prescriptions have been written. In many plans, however, such portions of the planning area are labeled fire management units or zones. To avoid confusion, the term "fire management area" should only be used to refer to the planning area.

FIRE MANAGEMENT UNITS AND ZONES

Fire management area is, as just indicated, the term used to denote a planning area. Fire management unit and fire management zone are terms used to denote parts of a fire management area. Fire management unit and fire management zone are often used as synonyms. They are not so used here. *A fire management unit is a distinct part of the fire management area that can be recognized and mapped from its external features.* A particular drainage within a fire management area is an example of a fire management unit. It is, in a sense, a mini-fire management area. *A fire management zone refers to all the land within a fire management area that has some common characteristic.* The shared characteristic can be physical, biological, or use-related, for example, all the land above 9,000 ft (2 743 m) or all land that comprises prime grizzly bear habitat.

FIRE MANAGEMENT PRESCRIPTIONS

A fire management prescription is a written direction for dealing with the threat, occurrence, and use of fire within a fire management area, unit, or zone. Note that the scope of a fire management prescription is broader than that of a fire prescription. A fire prescription is a written direction for the use of fire. Traditional fire prescriptions are usually limited in scope. They primarily deal with the conditions under which a fire will be ignited, ignition techniques, and other factors directly related to the conduct of a burn. A fire management prescription must include necessary direction for the detection, prevention, and suppression of fires as well as for the use of fire.

FIRE MONITORING AND EVALUATION

Fire monitoring is the act of observing a fire to obtain information about its environment, behavior, and effects for the purpose of evaluating the fire and its prescription.

Fire evaluation is the process of examining and appraising fire monitoring information.

Fire monitoring and evaluation provide information needed to (1) make daily decisions regarding a prescribed fire, (2) inform the public of fire activity, (3) comply with agency requirements for documenting fire management activities, and (4) determine how well a fire prescription is accomplishing its fire management objective.

A Prescribed Fire Monitoring and Evaluation Guide prepared by the Prescribed Fire and Fire Effects Working Team of the National Wildfire Coordinating Group (Van Wagtendonk and others 1982) is an excellent source of information on fire monitoring and evaluation.

A standard terminology is critical to progress in wilderness fire management. This suggested terminology may fall short of satisfying this need, but it can be a starting point.

In the meantime, managers and planners are cautioned to review agency policy regarding fire management terminology before using the suggested terms in plans or other official documents.

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WILDERNESS MANAGEMENT: A HISTORICAL PERSPECTIVE ON THE IMPLICATIONS OF HUMAN-IGNITED FIRE

William A. Worf

ABSTRACT: Early thinking on developing regulations to implement the 1964 Wilderness Act is reviewed. Discussion focuses on questions of how Forest Service wilderness management policy developed, how Congress defined "ecological naturalness," whether Mother Nature knows the difference between lightning fires and human-ignited fires, whether Congress considered the activities of aboriginal humans a part of the land's natural character, whether the use of scheduled fire[1] to achieve wilderness resource objectives is consistent with the spirit and intent of the 1964 Wilderness Act, and whether there are other objectives for which the use of scheduled fire would be consistent with the Act's provisions. The author concludes that using prescribed fire with scheduled ignitions as a tool to manage the wilderness resource is inappropriate. However, he believes scheduled ignitions can be used with caution to control fires as in national parks or wildlife refuges to meet special park or refuge objectives.

Interest in the Wilderness Fire Symposium was given impetus and was coincident with a proposed change in Forest Service, U.S. Department of Agriculture, policy regarding scheduled fire in wilderness. That change was expressed in a Forest Service fact sheet dated September 15, 1983:

> The Forest Service is revising its wilderness fire management policy to permit prescribed fires ignited by trained professionals to be used in wilderness areas to meet wilderness resource objectives. Prescribed fires in wilderness would occur on a very limited basis. Each fire would be authorized by the appropriate Regional Forester, and would be ignited only after a team of experts in various fields of resource management determined that lightning-caused fires were too infrequent to meet wilderness resource objectives or that an uncontrolled lightning fire could cause unacceptable damage to highly valued areas outside the wilderness. This revised policy would provide more timely restoration of wilderness characteristics than the current policy of waiting for the work to be totally accomplished by lightning fires--an unpredictable approach at best. It would also provide a means of reducing or minimizing the adverse impacts of wildfire in wilderness and on adjacent lands and resources. (emphasis added)

I have serious personal doubts that the proposed policy change is consistent with the letter or spirit of the 1964 Wilderness Act. In any event, this is a complex issue that requires a great deal of careful study and much public debate. Some of the most important values of our wilderness system may be at stake.

According to Dr. Don Despain (this Proceedings):

> Our continued existence on this planet depends on how in tune we can become with environmental forces . . . . We need to learn more about the forces that shaped the ecosystems in which we live in order to fit ourselves into the ecosystem rather than being constantly at war with natural forces. To do this we need some areas where fire can respond to all the environment conditions without our interference. This includes both time and place of ignition.

In exploring the issue, I will treat the following questions in this paper:

1. How was Forest Service wilderness management policy developed?

2. What ecological naturalness did Congress have in mind when it directed agencies to administer wildernesses in such a way as "to preserve its wilderness character"?

3. Does Mother Nature really know the difference between lightning fires (unscheduled ignitions) and human-ignited (scheduled) fires?

4. Did Congress consider the activities of aboriginal humans a part of the "natural character" of the land?

5. Is the use of scheduled fire to achieve wilderness resource objectives consistent with the spirit and intent of the 1964 Wilderness Act?

Paper was invited for inclusion in the Proceedings of the Symposium, Wilderness Fire, by James E. Lotan.

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[1]Editor's note: please refer to Foreword for comments on prescribed fire terminology.

6. Are there any other objectives for which the use of scheduled fire would be consistent with the provisions of the 1964 Act?

HOW WAS FOREST SERVICE WILDERNESS MANAGEMENT POLICY DEVELOPED?

I believe that this question is vital to the issue at hand because it will help to bring a bit more objectivity into a highly subjective question: "What is wilderness?"

As you know, the Forest Service has been involved with wilderness since 1924, and in 1964 Congress accepted 54 of its administratively designated areas as the nucleus of the National Wilderness System. Accordingly, the Forest Service had an instant wilderness management job as soon as the Act was signed on September 3, 1964. The Chief immediately put together a task force to develop regulations and policy guidelines. The task force was led by Gordon Hammond, who worked for the Director of Recreation, Richard Costley, in the Washington Office. I was privileged to have served on that task force along with Ed Slusher (Northern Region wilderness staff), George Williams (Pacific Northwest Region wilderness staff), Arne Snyder (ranger in the High Sierras), and Bill Brizee (attorney in the Secretary of Agriculture, Office of General Counsel).

All members of the task force had firsthand experience in managing National Forest wildernesses, and we approached the job with self-confidence and a conviction that we would wind up the task in short order. After all, the Forest Service had been managing wilderness for over 40 years. Hadn't Congress validated what we had been doing? Our job appeared to be simple--just put 40 years of experience on paper. We were in for a rude awakening! From the onset, the six of us could not agree as to what wilderness was or what activities were or were not appropriate in its management. On points where we agreed, other Forest Service administrators disagreed. The Forest Service wilderness management policy was not well understood nor uniformly applied. Each National Forest wilderness had been managed differently, and management sometimes changed with each change of managers assigned to the area. We had discovered one of the reasons why the Wilderness Act had passed in 1964.

Congress had established a national policy "to secure for the American people . . . an enduring resource of wilderness." Supporters of the Act believed that this long-range objective could only be achieved by <u>strict</u> and <u>consistent</u> direction. They felt that management should not be based on rationalizations of the moment or the personal philosophy of an incumbent manager. Congressman John Saylor, who had introduced the first wilderness bill in the House, made that point when he placed the summary of the Outdoor Recreation Resource Review Commission's Study Report No. 3 in the Congressional Record (1963). Saylor stated in that document:

> Mr. Speaker, fortunately we do have areas of wilderness in our national ownership. How we handle them, how we administer them, will determine whether we shall continue to have them.
>
> This report points out four ways in which our wilderness in public ownership can pass away:
>
> First. Our land-administering agencies can put it to other uses.
>
> Second. Our agencies lack full jurisdiction over other uses that the lands, now wilderness, can be made to serve.
>
> Third. There is a "lack of coordinated control over wilderness uses."
>
> Fourth. There is at present a "lack of distinctiveness in management policy," which can result in subtle deterioration of the resource itself.
>
> To avoid these hazards to wilderness preservation, we accordingly need sound and effective administration, and this can be accomplished only along guidelines that Congress must provide.

It became clear to the task force that Congress had intended to set forth a clear wilderness management direction and to set it down in law so that it could never be changed administratively. We examined that direction carefully. We recognized that uses and values vary between the various units of the wilderness system. Accordingly, uses that are accepted and management practices that are necessary in one wilderness may be unacceptable or unnecessary in another. These differences require flexibility in the management of individual units. Nevertheless, all wilderness is a part of the National Wilderness Preservation System, and certain basic philosophical principles must consistently be applied. Without a clear statement and strict adherence to these principles, management decisions would be left to rationalization of individual managers based upon personal views of wilderness. One honest and conscientious manager might approve a management practice that would be later disapproved by another equally honest and conscientious manager.

The job of developing wilderness policy became a straightforward one. As each management issue was raised, we tested it against the Act, its legislative history, and previous decisions. Our resident attorney, Bill Brizee, helped keep us legal. To the best of our ability, the policy that emerged was an objective representation of the intent of Congress. The process has continued over the years as new issues emerged.

WHAT ECOLOGIC NATURALNESS DID CONGRESS HAVE IN MIND WHEN IT DIRECTED AGENCIES TO ADMINISTER WILDERNESS IN SUCH A WAY AS "TO PRESERVE ITS WILDERNESS CHARACTER"?

The answer cannot be left to the subjective judgment of each individual manager. It was one of the most difficult issues that faced the Forest Service policy development task force when it convened in 1964. I was initially convinced that our objective should be to maintain a natural "appearance." Anything that could be done unobtrusively to maintain or enhance esthetics, wildlife (especially big game), grazing for livestock, or water yield was fully consistent with my personal philosophy. George Williams, whose career had been in the Pacific Northwest and who had worked closely with conservation groups during the 8-year debate over wilderness legislation, disagreed strongly with me. Ed Slusher, with his background in Montana and Idaho wildernesses, and Arne Snyder from the High Sierras were someplace between George and me on this issue. Gordon Hammond and Bill Brizee served as referees and helped us search for common ground.

The debate continues today. Mr. Douglas MacCleery, Deputy Assistant Secretary of the U.S. Department of Agriculture, seems to believe that our objective should be to "perpetuate naturally occurring vegetative types" and maintain optimum diversity. Speakers in this Symposium have expressed widely varying beliefs on this issue. Some suggest that our objective should be to maintain or reestablish the vegetation that existed when Europeans first came to America. Some suggested that stand replacement or "catastrophic" fires, even though natural, are undesirable and damaging to wilderness because of their severe esthetic impact.

The Outdoor Recreation Resource Review Commission (1962) spoke about the meaning of natural conditions. It said:

> The most important characteristic of nature and natural conditions presumably epitomized in wilderness, and often ignored in popular interpretation of nature, is change. A constant interplay of forces like fire, wind, flood, disease, or more subtle effects of natural plant succession and animal population fluctuations, represent an integrated biological dynamism, which most aptly distinguishes natural condition.

Howard Zahniser (1955), one of the most important drafters and promoters of the 1964 Act, said:

> In addition to our need for urban and suburban parks and open spaces, in addition to the need for a countryside of rural loveliness, a landscape of beauty for all kinds of outdoor recreation, there is in our planning a need also to secure the preservation of some areas that are so managed to be left unmanaged--areas that are undeveloped by man's mechanical tools and in every way unmodified by his civilization.

Senator Hubert Humphrey (1956-57), who introduced the first wilderness bill in 1955, said in describing the objectives of his efforts:

> The wilderness Bill, in brief, is a measure designed to make sure that some parts of America may always remain unspoiled and beautiful in their own natural way, untrammeled by man and unmarred by machinery.

The basic purpose of the 1964 Wilderness Act itself (section 2[a]) is given as:

> In order to assure that an increasing population, accompanied by expanded settlement and growing modernization, does not occupy and <u>modify</u> all areas within the United States . . . . (emphasis added)

The Act defines wilderness ideally:

> ...as an area where the earth and its community of life are <u>untrammeled</u> by man . . . . (emphasis added)

In its April 3, 1963, report on S.4, the Senate Committee on Interior and Insular Affairs presented a long list of quotes from scientist and scientific groups to illustrate the scientific, educational, and historic values of wilderness. Following is a typical portion of that paper:

> Excerpts from the statements of a few of the many educators, scientists and scientific groups who have supported a wilderness preservation system, are indicative both of the separate and interrelated values which will flow from natural areas and must be appraised in making a sound determination on the desirability of setting aside primitive areas for protection as such.

Dr. Walter Cottam, professor of botany at the University of Utah, testified:

> Besides the great spiritual and recreational blessings afforded to all the people living and unborn, this bill also provides laboratory sanctuaries for biological research that should prove to be of inestimable academic and economic worth. One of the most perplexing problems in land management today is the lack of available wilderness areas from which comparisons can be made and lessons learned on the life histories, on food chains, and other ecological interactions of myriads of living forms whose impact on the future of man himself may well prove to be far greater than any of us can possibly realize.

Speaking as an educator, Dr. Angus M. Woodbury, emeritus professor, University of Utah, testified:

> The bill sets us areas which can be used as yardsticks, or experiments, by which things as they are in used areas, can be compared with these as they were before they were disturbed, and this proposal to make everything available for use destroys that ability, especially for educators who need samples which they can teach to their children or to their students, to show what was, as a basis for comparison, for the future guidance and control of biological resources in the country.

A resolution of the Wildlife Society, composed of scientists concerned with wildlife management, adopted in 1947, and reiterated at the committee's hearings, said:

> The remnants of primitive America are of irreplaceable value to science as sites for fundamental research and as check areas where none of the human factors being compared by investigators have been operative.

Faced with this evidence, the Forest Service wilderness policy development task force concluded that a fundamental purpose of our wilderness system was to maintain areas where natural processes would be allowed to operate without human control or direction. We drafted regulations that said in part:

> Natural ecological succession will be allowed to operate freely to the extent feasible.
>
> All resources will be managed in such a manner as to promote, restore, and perpetuate wilderness values.

More than 18,000 copies of the draft regulations were circulated for public comment, and these two sentences received a lot of fire. Some typical responses follow.

Mr. Reynolds T. Harnsburger, National President of the Izaak Walton League, said (Worf 1966):

> The phrase "to the extent feasible" of paragraph 1(a) of the regulations (page A-2) completely negates the thrust of the sentence. We believe the phrase should be deleted . . . .

Mr. Thomas Kimball, Executive Director of the National Wildlife Federation, said (Worf 1966):

> In our opinion, the phrase "to the extent feasible" either should be eliminated or modified to explain who will make the determination on feasibility and what factors might be considered of such value as to warrant change in the ecological succession.

Mr. Les Davis, President of the New Mexico Cattle Growers Association, said:

> Nowhere in the legislation do we find any reference to the "restoration" or "management" of the wilderness areas. Congress did not intend to appropriate money to let the hand of man create what man thinks a wilderness should be. Wilderness by its very nature means nature's management, "untrammeled by man, a place where man is just a visitor." We feel all reference to man's restoration and management except as specified by Congress should be stricken from the proposal.

These quotes provide the flavor of most reactions to our draft regulations. There were four comments that gave a different reaction. They came from Mr. Elliot S. Barker, former Secretary of the New Mexico Wildlife and Conservation Association; Mr. O. M. Lassen, State Land and Water Commissioner, Arizona State Land Department; Mr. Thomas M. Messelt, Great Falls, Mont.; and Mr. Roger M. Williams, Acting Director of the Idaho Fish and Game Department. The following quote from Mr. Williams' letter (Worf 1966) characterizes these four viewpoints:

> Paragraph "a" on page A-2, mentions natural succession being allowed to operate freely, and paragraph "3.a." on pages B-6 and B-7, mentions limitations on the manipulation of vegetative types.

> In portions of Idaho wilderness areas wildfires in coniferous timber have created vast areas of browse plants which provide the food base for large elk populations. Natural vegetative succession is slowly reducing the numbers of elk which can be carried on these ranges, and in the future some form of habitat manipulation may become necessary to maintain the present quality of wilderness elk hunting.
>
> We are concerned with the possibility that statements in the above mentioned paragraphs may be interpreted as prohibiting prescribed burning, application of herbicides, and perhaps other land treatment measures for the purpose of creating or improving winter range for these highly important elk herds. Research being conducted on this problem at the present time may suggest that some form of "manipulation of vegetative types" contrary to "natural ecological succession" is necessary for fulfillment of big game management objectives. We suggest that regulations make provision for this future possibility with the understanding that it be carried out in a manner in keeping with the wilderness values of these areas.

After reviewing the Act, its legislative history, and comments on our draft regulations, Chief Ed Cliff and Secretary Freeman concluded there was no doubt about the intent of Congress, the majority of which had suggested the wilderness legislation. We were to do our best to let natural processes work, and we were to let these processes work with whatever ecological situations existed at the time an area is designated as wilderness. There was to be no attempt to roll back the ecological clock to some selected date in history. The regulations were issued May 31, 1966, and the first objective was not changed from our July 19, 1965, draft: "Natural ecological succession will be allowed to operate freely to the extent feasible." It remains unchanged in the regulations today (see CFR 293.2[a]).

We retained the phrase "to the extent feasible" in spite of the public objection because we knew that we would have to control some fires and take some management actions to accommodate users covered by the Special Provision of the Act that would affect natural succession. We also retained the word "restore" in the regulations to support manual direction to erase physical evidence of human activities under the special provisions of Sec. 4(d) of the Act. It was not intended as a license to engineer ecological processes.

Chief Cliff recognized, and Congress recognized, that letting natural processes operate freely is an ideal that cannot be fully reached; however, we must aim to come as close to the ideal as feasible, rather than setting up an approximation of natural conditions as the goal.

There are some pervasive civilization-caused changes that wilderness managers cannot directly control or undo, such as increased air pollution. The Act also continued livestock grazing and other uses that can influence natural processes, and we know we will have to control some naturally ignited fires. Beyond this, wilderness exists to provide benefits, to be used as wilderness, particularly for scientific and educational purposes and for recreation and inspiration. This means <u>some</u> modification is unavoidable, but management of these primary wilderness uses must seek to minimize their impact. The specifically excepted, nonwilderness uses must be side benefits. Manipulating natural processes to enhance human uses is unacceptable. We recognized that effects of some types of manipulation might be "substantially unnoticeable" and might not impair recreational use and enjoyment. This fact, however, is no basis for deliberate action to modify natural processes, because this <u>would</u> still impair scientific and educational values of wilderness which are as important as recreation and scenery. The qualifications on pure wilderness in section 2(c)(1) of the Wilderness Act are an acceptance of unavoidable modifications, <u>not</u> an endorsement of deliberate change.

Nature is amoral, and in wilderness we allow it to be itself. There are no "good" or "bad" species or changes in nature; there are only human standards related to particular uses. This includes changes caused by natural fire--even high-intensity fire. Elk may diminish and pine squirrels increase as a result of natural processes; if so, in a wilderness we watch it happen, and some recreational uses may suffer. Another time or place, elk numbers may boom and related uses will benefit. Wilderness use, whether recreational or scientific, takes the wilderness as it is. It cannot do anything else and be wilderness use. Experiencing, contemplating, studying the uncontrolled ecosystem, and facing the challenge and adventure of traveling and living without mechanized aids is the "wilderness experience." There will often be better places than wilderness to catch fish or see elk; places where management is directed to maintain these opportunities. This does not make wildernesses unappealing. For the uses dependent on wilderness, letting nature operate freely is the way to make a wilderness as appealing as possible.

DOES MOTHER NATURE REALLY KNOW THE DIFFERENCE BETWEEN LIGHTNING FIRES (UNSCHEDULED IGNITIONS) AND HUMAN-IGNITED (SCHEDULED) FIRES?

Many people argue that we need to use scheduled fire to compensate for the lightning fires that have been controlled over the years or as a substitute for natural fire in those areas where natural fire would endanger surrounding resources or property. Dr. Bruce Kilgore (1983) says:

> Where the objective is to restore natural processes and to perpetuate natural operation of ecosystems, as in the National Parks and the Forest Service-administered wilderness areas, such an objective can be achieved either by allowing natural (usually lightning) ignitions to burn under specified conditions or by choosing appropriate conditions for deliberate ignition of prescribed burns.

Conceptually speaking, the answer to this question is probably no. If we deliberately ignite a fire on comparable topography and in a comparable vegetative situation at the same moment that lightning ignites a fire, we could expect ecological effects to be similar. Likewise, if we made a computer analysis of the lightning starts that have been suppressed over the past 20 years or so, then went in and reignited them on the identical spot under the identical weather conditions that existed previously, we might achieve a near-natural result.

In a practical sense, however, we will not fool Mother Nature. No fire specialist I know is proposing to go out on a hot August afternoon with fire danger at extreme and start setting fires. Yet before humans started suppressing them, lightning fires started under those conditions probably accounted for most of the burned acres. In the real world, managers responsible for igniting prescribed fire, as Dr. Kilgore suggests, choose "appropriate conditions." If we had the money and <u>if</u> we had the commitment to tackle the job for an entire wilderness, we might come close over an 8- to 10-year period to applying fire to the same acres that would have burned with lightning fires. We would not, however, even come close to matching the fire intensity or the seasonal timing that would have been applied naturally. We would establish a <u>fire</u>-dependent cover, but it would be totally different than a <u>natural fire</u>-dependent vegetative cover. It would be just a different human-caused condition than the current one.

In the real world of scheduled fire, where humans choose the "appropriate conditions," fire ceases to be a natural force and becomes a manipulative tool. Conceptually, scheduled fire is no different than herbicides, a chain saw, or an anchor chain between two D-8's. In fact, these tools can be applied with a great deal more precision and more predictable results than scheduled fire. Dr. Despain said elsewhere in these proceedings:

> Our state of knowledge is such that prescribed fire cannot be expected to mimic natural results.

In short, you can't fool Mother Nature. She does know the difference between a drip torch and lightning.

DID CONGRESS CONSIDER THE ACTIVITIES OF ABORIGINAL HUMANS A PART OF THE "NATURAL CHARACTER" OF THE LAND?

There is no doubt that the Native American used fire to achieve a number of objectives. The Indians also altered natural ecological processes in other ways. They cultivated maize and other crops, large horse herds overgrazed localized areas, and large encampments compacted soil.

Several speakers in the Symposium have expressed their conviction that we should recognize aboriginal fire as a part of the natural character of the land. This discussion is important to understanding the ecological situation we find in wildernesses today, but we need to look at the 1964 Act and its history to determine how we should apply this knowledge to management of the National Wilderness Preservation System. The Act says wilderness must be "untrammeled by man" and that the evidence of "man's" works shall be substantially unnoticeable. Similar language was used over and over again between 1956 and 1964 by people explaining what legislation would accomplish. Senator Clinton Anderson (1964) said on the occasion of adoption of the conference report:

> We have set aside part of our land as it was when human eye first saw it--unscarred by man, primeval a memorial to the creator who molded it.

I find nothing to indicate Congress intended that managers should attempt to perpetuate the environmental effects of aboriginal man much less pick out one of these--fire--for special application.

IS THE USE OF HUMAN-IGNITED (SCHEDULED) FIRE TO ACHIEVE WILDERNESS RESOURCE OBJECTIVES CONSISTENT WITH THE SPIRIT AND INTENT OF THE 1964 WILDERNESS ACT?

As stated in response to an earlier question, I believe that scheduled fire is simply a tool for manipulation. There is overwhelming evidence that manipulation is the antithesis of wilderness. In National Forest wildernesses scheduled fire to achieve wilderness resource objectives would also be inconsistent with current Secretary of Agriculture regulations.

ARE THERE ANY OTHER OBJECTIVES FOR WHICH THE USE OF SCHEDULED FIRE WOULD BE CONSISTENT WITH PROVISIONS OF THE 1964 ACT?

Yes. Section 4(d)(1) of the Act gives the Secretary of Agriculture authority to take "measures" necessary to control fire, insects, and disease. We do have some wilderness where natural or human-caused wildfires would endanger resources or property outside the wilderness. If it can be shown that scheduled fire to reduce fuel levels or establish fuel breaks is necessary to assure adequate control, its use would be legally authorized. It must be recognized, however, that the wilderness resource will be the loser, not the benefactor. Accordingly, the following constraints should apply: (1) such work should be done outside the wilderness whenever possible; (2) work done inside the wilderness should be planned and executed in a manner that will have the least possible impact on wilderness values and users; and (3) an integral part of every project should be careful monitoring to measure actual results against planned objectives.

Also Section 4(a) of the Wilderness Act states:

> The purposes of this Act are hereby declared to be within and supplemental to the purposes for which the national forests and units of the national park and national wildlife refuge system are established and administered . . . .

The National Park Service and the Fish and Wildlife Service must sometimes take manipulative action to achieve broader park or refuge mandates. Where scheduled fire is clearly necessary for these reasons, its use is legally permitted. Once again, it must be recognized that the wilderness resource suffers, and the coordinating measures listed above should apply.

In conclusion, the wilderness idea has been growing in America for at least 130 years. The climax of the movement came in 1964, when our Congress after 8 years of debate established a policy to "secure for the American people of present and future generations the benefits of an enduring resource of wilderness . . . ." Although wilderness is a subjective term that means different things to different people, Congress knew that any system that was to endure had to be based on clear principles that only Congress could provide. A cornerstone of the wilderness concept defined by the 1964 Act is that humans will take no avoidable deliberate action to interfere with natural ecological processes. We now have nearly 20 years of experience with this concept, and I see no evidence that the mood of the Nation has changed, or that it now wants wilderness managers to gently manipulate nature to optimize human benefits from wilderness areas. If, however, the proposed change in Forest Service fire policy seems to be needed and appropriate, it should be initiated in the same manner as the direction established in 1964.

Let me close with words Howard Zahniser wrote in 1955:

> It behoves us then to do two things: First, we must see that an adequate system of wilderness areas is designed for preservation, and then we must allow nothing to alter the wilderness character of the preserves.
>
> We have made an excellent start on such a program. Our obligation now--to those who have been our pioneers and to those of the future, as well as to our own generation--is to see that this program is not undone but perfected.

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HUMAN-IGNITED PRESCRIBED FIRES IN WILDERNESS:

A RESPONSE TO BILL WORF

Bruce M. Kilgore

After analyzing Bill Worf's challenge to the proposed occasional use of human-ignited prescribed fire in wilderness to meet wilderness resource objectives, I find I agree with much of the philosophical content of Worf's paper and much of his philosophical value system. Where I disagree is in the application of these principles or philosophical points to on-the-ground management actions. In other words, we seem to have the same objectives, but somehow we see different solutions or actions as better achieving our common purpose.

AREAS OF AGREEMENT

I agree with Worf that the issue is extremely important and that, "Some of the most important values of our wilderness system may be at stake." I also agree with Don Despain (quoted by Worf) that, ". . . we need some areas where fire can respond to all the environment conditions without our interference. This includes both time and place of ignitions." And I certainly agree with Howard Zahniser (quoted by Worf) about the need ". . . to secure the preservation of some areas that are so managed as to be left unmanaged . . . in every way unmodified by . . . civilization."

In summary, I agree with the philosophy expressed by these Worf comments:

> 1. . . . letting nature operate freely is the way to make a wilderness as appealing as possible . . . There are no "good" or "bad" . . . changes in nature . . . . This includes changes caused by natural fire--even high-intensity fires . . . [but] letting natural processes operate freely is an ideal that cannot be fully reached. However, we must aim to come as close to the ideal as feasible . . . .
>
> 2. . . . we know we will have to control some naturally ignited fires . . . some modification is unavoidable, but management . . . must seek to minimize impact . . . manipulating natural processes to enhance human uses is unacceptable.
>
> 3. . . . [any use of scheduled fire] should be done outside the wilderness whenever possible; (2) work done inside the wilderness should be planned and executed in a manner that will have the least possible impact on wilderness values . . .; and (3) an integral part of every project should be careful monitoring to measure actual results against planned objectives.

AREAS OF DISAGREEMENT

I disagree with Worf in his basic assumption that use of human-ignited prescribed fire is appropriate only if fire control needs require it. Even where there have been major human-caused changes in certain wilderness ecosystems, this view holds that no action (except occasional fire control) is preferable to (1) using prescribed fire to restore an approximation of natural conditions followed by (2) letting nature take its course. Yet allowing "some" natural lightning ignitions to burn will not bring about a natural state of wilderness. This is especially true in ecosystems where unnatural fuel buildup and unnatural forest structure has resulted from 50 to 80 years of fire suppression/exclusion efforts. Specifically, I am concerned that as much as we would wish otherwise, Earth and its community of life in most wilderness areas are not completely "untrammeled by man." Some wildernesses will never receive fire naturally because they represent higher-elevation remnants of natural systems where fires started at lower elevations and burned upslope. Such lower elevation ignitions are now quickly suppressed or, in some cases, the vegetation has been altered so that no natural fuels even exist there. I feel that an important priority for future wilderness fire research is to determine which ecosystems have been most affected by fire exclusion and how strongly impacted they have been. Another and even more important priority is to determine what can be done about the changes in these wilderness ecosystems in a manner which will be most

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Paper invited by James E. Lotan following the Wilderness Fire Symposium, Missoula, Mont., November 15-18, 1983

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consistent with the broad objectives of wilderness preservation and perpetuation.

My strongest concern is that the ideal condition described by Howard Zahniser in 1955, namely a wilderness ". . . in every way unmodified by civilization," no longer exists even in the most remote wilderness ecosystems (van Wagtendonk; Habeck; Brown; Bonnicksen; others this proceedings). In the case of ponderosa pine and mixed-conifer ecosystems of the Southwest and the Sierra Nevada, where intervals between fires are on the order of 5 to 20 years, exclusion of fire for 50 to 80 years may have had a substantial impact on the combination of fuels and forest structure (Cooper 1960, 1961; Kilgore and Sando 1975; Kilgore and Taylor 1979; Parsons and DeBenedetti 1979; Bonnicksen and Stone 1982a). On the other hand, in ecosystems where intervals between fires are from 100 to 300 or more years, in all likelihood fire suppression would have had less impact to date (Habeck this proceedings).

There are several solutions to this problem of human-caused changes in wilderness ecosystems. We can decide that it is impossible to erase changes already made and choose to make no attempt to offset any abnormal fuel and forest structure situations. This solution would simply let natural processes, including fire ignited by lightning in the next few decades, operate within the existing conditions, whatever they may be. An alternate solution would be a conscious effort to define how much change has taken place in particular ecosystems most likely to have been impacted (those with fire regimes involving frequent fires [Kilgore 1981]). Then, carefully planned prescribed fires can be used to approximate restoration of conditions that would have been found had natural ignitions been allowed to burn during the past half century. Bill Worf would favor the former alternative. I would favor the latter. I feel that the whole fire management program in wilderness could be jeopardized if managers allow lightning-caused fires to run their course in wilderness units where fuel has accumulated or stand structure has changed as a result of fire suppression to the point that unnaturally large and intense fires would now burn.

As noted earlier in discussing areas of agreement, Bill Worf acknowledges that some management actions will have to be taken that are not consistent with letting nature take its course. He says, ". . . we knew that we would have to control some fires . . . ." and that "Natural ecological succession will be allowed to operate freely to the extent feasible." Ironically, these are critical management actions determining the future state of the wilderness. If we agree that some management actions must be taken (some fires will be suppressed), then I must accept the conclusion that our management programs cannot be totally pure; yet we are aiming for the nearest approximation of natural conditions we can achieve. This goal of coming as close to the ideal as feasible can be best achieved, in my opinion, by use of prescribed fire in those systems where restoration of more natural fuel loadings and forest structure is needed.

There are many difficulties in using prescribed fire to restore "natural" conditions; among them is determining what forest structure would be now had we not interfered with natural fires for the past half century or more (Bonnicksen; Kilgore; van Wagtendonk this proceedings). There are even more problems in deciding how to restore more natural fuel accumulation and forest structure, or even if this needs to be done (Bonnicksen and Stone 1982b; Parsons and others in press; Bancroft and others this proceedings). Once this initial restoration has been accomplished, wilderness managers would in most instances be philosophically in a position to simply let nature take its course. Whether this will be possible in practice is another question which varies to some extent geographically and politically, particularly in ecosystems which support high-intensity, stand-replacing fires (Heinselman; Kilgore this proceedings).

Worf is no doubt correct in his contention that efforts to restore more natural conditions through use of prescribed fire would be carried out under conditions less severe than those under which nature might have burned on a hot August afternoon. However, the implied criticism that these would not be "natural" burns and hence just another human-caused abnormality seems off target. The prescribed fire would come as close to the ideal as feasible, certainly more philosophically acceptable than "a pair of D-8 cats" used to suppress a lightning fire.

Simply waiting for the next lightning ignition to solve our dilemma is a "cop-out" in the sense that we would be trying to pass the responsibility to Mother Nature to solve a problem we created. Through fire suppression, it appears we have altered the forest structure and fuel loading beyond that found naturally in certain ecosystems; as such, we have tied one hand behind her back. Instead, we must first take action (1) to learn more about the present status of the particular wilderness forest fuels and structure and (2) to restore more natural conditions based on that best current knowledge. Then it would be reasonable to let the next lightning ignition take its course. I can relate to Don Despain's point (quoted by Worf) that we do not yet know enough to mimic natural results exactly. Still, I feel that employing our best knowledge of prescribed fire is preferable to ignoring the problem. If additional data about fire history (intervals, severity, intensity, and seasons) in a particular ecosystem or geographic area will allow us to better simulate natural processes and conditions, then we should move quickly to obtain that information and integrate it into our plan for initial restoration. Our long-term management goal should be to return the processes of nature "to the extent feasible."

CONCLUSION

Bill Worf and I have no disagreement about the cornerstone of the wilderness concept being "that man will take no avoidable deliberate action to interfere with natural ecological processes." My concern is that we have already interfered with such natural processes for 50 to 80 years or more. Therefore, it seems totally unreasonable to me to now simply accept that a natural (lightning) ignition burning into an unnatural (human-caused) accumulation of fuels and an abnormal forest structure (unusually heavy vertical fuel ladders and abnormally uniform horizontal mosaic patterns) will somehow result in what Congress and Howard Zahniser had in mind--namely a natural wilderness "untrammeled" by man. I agree with Howard Zahniser that we must be guardians, not gardeners. However, in my opinion, responsible guardianship will in some cases require interim application of carefully planned prescribed fire. This will apply only in those ecosystems where research indicates there has been a major change because of human-caused fire exclusion. In this way we can ultimately approach the ideal of letting natural processes operate freely while minimizing the impacts of human actions--past and present--on wilderness ecosystems.

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PLANNED IGNITIONS IN WILDERNESS:

RESPONSE TO PAPER BY WILLIAM A. WORF

Robert C. Lucas

INTRODUCTION

Bill Worf's contribution to these symposium proceedings raises important issues about the possible use of planned ignitions in national forest wilderness. By planned ignitions I mean fires ignited deliberately by wilderness managers. (Elsewhere in this symposium Fischer calls such fires "scheduled ignitions.") Worf provides a good review of development of Forest Service wilderness policy and of the standard of naturalness intended by the 1964 Wilderness Act. I agree with Worf on these two points, but I disagree with his rejection of planned ignition as a wilderness management tool.

I will discuss five questions that are fundamental to this issue:

1. Why not suppress all fires in wilderness?

2. Why not depend entirely on natural lightning ignitions?

3. Are planned ignitions in wilderness legal?

4. Are planned ignitions in wilderness consistent with the spirit and philosophy of wilderness and the Wilderness Act?

5. Can managers be trusted to apply a planned ignition policy?

WHY NOT SUPPRESS ALL FIRES IN WILDERNESS?

Until recently, all fires were suppressed as quickly as possible in wilderness and parks. In areas without approved fire management plans, they still are. But beginning shortly before passage of the Wilderness Act in 1964, some scientists began to recognize that suppressing all wildfires in wilderness was inappropriate (ORRRC 1962; Leopold and others 1963; Heinselman 1978). Fire suppression contradicted the objective in the Act (Sec. 2(a)) to assure that American civilization "does not occupy and modify all areas within the United States and its possessions, leaving no lands designated for preservation and protection in their natural condition . . . ." Fire suppression also contradicted the definition of wilderness (Sec. 2(c)), part of which is "an area where the earth and its community of life are untrammeled by man" and "which generally appears to have been affected primarily by the forces of nature." ("Untrammeled" means unconstrained, unfettered, or unshackled.) Scientific knowledge grew, making it increasingly clear that wildfire had been an important "force of nature" in most wildernesses and the dominant force shaping vegetation and animal communities in many areas. By aggressively seeking to suppress all wildfires, man was clearly "trammeling . . . the community of life" and substantially modifying natural conditions in wilderness.

The National Park Service responded first, changing fire policies in Sequoia and Kings Canyon National Parks to allow certain lightning fires to burn naturally in 1968. In 1969, planned ignitions began (Kilgore 1983). The Forest Service shifted its policy first in part of the Selway-Bitterroot Wilderness in 1970 (Aldrich and Mutch 1972). Now, more than 16 million acres in national parks and national forest wildernesses are included in fire management plans designed to let fire more nearly play its natural ecological role (Kilgore 1983). Bill Worf supports this policy, so do I, and so do most people concerned with wilderness management.

WHY NOT DEPEND ENTIRELY ON NATURAL LIGHTNING IGNITIONS?

Ideally, we would allow all lightning-ignited fires to run their course. If all lightning fires burned uncontrolled as they once did, the full, free action of fire, with all its natural variability, would be restored. Unfortunately, this is impossible for at least three good reasons:

1. Some lightning fires must be suppressed, because under more severe fire danger conditions, they pose an unacceptable risk to visitors, to agency and inholder facilities (trail bridges, fences, cabins, etc.), and to areas outside the wilderness managed for different values and objectives. Generally, only lightning fires predicted

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Paper invited by James E. Lotan following the Wilderness Fire Symposium, Missoula, Mont., November 15-18, 1983.

Robert C. Lucas is principal research social scientist and project leader of the Intermountain Station's Wilderness Management research work unit at the Forestry Sciences Laboratory in Missoula, Mont.

to be small, low intensity, and safe meet criteria for classification as a prescribed fire that may be permitted to burn.

2. Lightning fires originating outside the wilderness, and that would have burned into wilderness under natural conditions, are usually immediately suppressed. This source of natural fire is thus greatly reduced.

3. In some wildernesses, especially those where natural fire was frequent, effective fire exclusion has resulted in unnatural fuel and forest stand conditions that could result in intense fires and high risks of the type discussed under reason 1. Where this condition exists, it forces managers to develop restrictive prescriptions that limit the number of lightning fire starts that will burn under prescription. It also increases the prospects of an uncontrollable, unusually high-intensity wildfire, causing unnatural ecological results.

The first national forest wilderness, the Gila in New Mexico, is an example of the problems of depending on prescribed lightning fires to play their natural role. A fire history study estimated that prior to the institution of fire control in 1900, much of the area burned, usually in moderate surface fires, about every 5 to 8 years. From 1900 to 1975, almost all fires were quickly put out (Swetnam 1983). In 1975, a wilderness fire management plan was approved. Perhaps 10 to 15 fires that might have affected much of the Gila Wilderness had been skipped over between 1900 and 1975 because of fire suppression. Dog-hair ponderosa pine thickets developed (Swetnam 1983). In the first 8 years of the fire management plan, only 11,000 acres (≅4 500 ha) burned under prescription out of 310,000 acres (≅125 000 ha) in the plan--less than 4 percent of the area. If the natural fire regime was fires at 5- to 8-year intervals, one might have expected burned acres to total 100 percent or more of the area in 8 years. But so far, lightning fires burning under prescription are barely making a dent in perpetuating the natural interplay of ecological forces in the wilderness Aldo Leopold was instrumental in creating.

Planned ignitions can play two roles in such situations:

1. A transition to more natural ecological conditions. Over a period of years, managers would seek to undo some of the unnatural changes to the wilderness resource from years of fire exclusion. If they succeed, not only will more nearly natural conditions result, but, as fuel conditions become more natural, it may be possible to write less restrictive prescriptions and allow lightning fires to play a larger, more nearly natural role. Planned ignitions for this purpose would be temporary.

2. Even under the best of conditions, in most wildernesses prescriptions will require suppression of some fires, and fires starting outside wilderness usually will continue to be excluded. Fire inevitably will play less than its full natural role on a permanent basis. In some areas, fire's natural role may be only slightly reduced, but in others it could be severely curtailed. If managers feel that the reduction is unacceptably large, planned ignitions could, at least partially, fill the gap and produce a closer approximation of the ideal of free interaction of natural forces. Planned ignitions for this purpose would be permanent.

ARE PLANNED IGNITIONS IN WILDERNESS LEGAL?

Obviously, wilderness managers <u>must</u> obey the law. The National Park Service has been igniting planned fires for 15 years with no legal challenges yet. Congress has not expressed any concern or issued any guidelines for fire, as they have for wilderness grazing.

Congress did not specifically address the appropriate role of fire as a natural force in the Wilderness Act because it was an issue just starting to surface in the early 1960's. I can find no language that specifically bars either prescribed lightning fires or planned ignitions.

Section 4(d)(1) is the only mention of fire in the Wilderness Act. It states, "such measures may be taken as may be necessary in the control of fire, insects and disease, subject to such conditions as the Secretary deems desirable." Probably Congress' intent was to avoid tying managers' hands, and probably most of them were thinking of "control" only in terms of putting fires out. But "fire control" has evolved into "fire management" and the name of the Forest Service division has changed to reflect this evolution. Surely, planned ignitions to reduce the chances of large, intense, unnatural fires occurring is legitimately "control." So, too, I think, is planning for prescribed lightning fires. In fact, the legal authority and constraints for lightning fires and planned ignitions seem to be one and the same.

ARE PLANNED IGNITIONS IN WILDERNESS CONSISTENT WITH THE SPIRIT AND PHILOSOPHY OF WILDERNESS AND THE WILDERNESS ACT?

The wilderness idea and its expression in the Wilderness Act are intended to preserve some places where nature operates freely, where man can visit and experience a wild environment. Worf agrees; he points out that the Forest Service policy, based on its understanding of the Wilderness Act, has always been "natural ecological succession will be allowed to operate freely to the extent feasible."

In many places, the most powerful force in natural ecological succession was fire. Thus, managers have an obligation to minimize man's interference, past and present, with natural fire.

Clearly, this can almost never be done 100 percent, and the word "feasible" recognizes this limitation. Wildernesses exist today as islands in a sea of modification, subject to outside influences, often with nonnative plants and animals present, with certain native species eliminated in some areas, and affected by pervasive air pollution and recreational use.

Naturalness is a continuum, not a dichotomy. Prescribed lightning fires help a wilderness shift toward more natural conditions; planned ignitions can help managers move a wilderness closer to the natural ideal. This goal will be furthered as research yields more knowledge of fire-related natural processes.

CAN MANAGERS BE TRUSTED TO APPLY A PLANNED IGNITION POLICY?

Although Worf did not explicitly raise the question of trust, it does influence the concerns expressed by him and others. Many fear that managers would use fire not to try to more nearly let natural processes operate for wilderness purposes but to plan ignitions to improve elk winter range, to increase forage for domestic livestock, or enhance some other nonwilderness value. Whether managers do this deliberately or through insensitivity to wilderness objectives is irrelevant; the undesirable effects would be the same. The differences may be subtle; a fire for purely wilderness purposes often will also benefit big game, etc., but incidentally and usually not to the optimal degree that a fire designed for that purpose would.

The notice of proposed changes in the Forest Service Manual sections dealing with wilderness fire policy (2320.3e and 2324) was printed in the Federal Register, Vol. 49, No. 109, June 5, 1984, p. 23203. The policy seems to allow little opportunity for serious misapplication of planned ignitions. Any planned ignition must meet at least one of the following conditions:

1. Permit lightning-caused fires to more nearly play their natural role within wilderness.

2. Reduce the risk from wildfire, or its consequences, to life and property within wilderness or to resources, life, or property outside wilderness.

3. Maintain fire-dependent communities if the Act establishing the wilderness specifically directs their maintenance.

The manual specifically states that these are the wilderness fire objectives and that "although prescribed fire may indirectly benefit wildlife habitat, improve forage production, or enhance other resource values, the decision to use prescribed fire must be predicated on the above stated wilderness fire objectives."

In addition, the proposed policy requires that every planned ignition must meet <u>all</u> of the following criteria:

1. Lightning fires cannot be allowed to burn freely without unacceptable risk. (Except for a few very isolated wildernesses, such as islands, with substantially natural fuel conditions, there are probably no places where all lightning fires can burn freely.)

2. Wilderness fire policy objectives (the three above) cannot be achieved by using prescribed fire or other fuel treatment measures outside wilderness. (This would apply mainly to objective 2, above.)

3. An interdisciplinary team has evaluated and recommended the proposed use. (This should reduce the risk that one specialist, such as a wildlife biologist, could misapply planned ignitions.)

4. The interested public is appropriately involved in the decision.

5. The Regional Forester approves the decision.

CONCLUSION

This proposed policy governing planned ignitions in wilderness is not likely to produce hasty, distorted, surprise decisions. I do not know what more openness, control, and accountability could be reasonably expected. Some measure of trust seems justified as the policy is tried out, and as managers learn from their experience.

The complexity and controversial nature of the policy will assure that the trial will be slow and cautious. Limited funds for wilderness management, which would bear a large part of the cost of planned ignitions, should also help allay fears that firebugs will run amok in wilderness with drip torches in each hand. Caution will also be in order while research on wilderness fire expands knowledge.

To me, the long-term risks of damage to the wilderness resource from planned ignitions seem less than continuing to distort the role of a natural ecological force that dominated so many wildernesses before modern man interfered.

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Section 9. Reports of Interagency Workshop on Resolving Park and Wilderness Fire Management Issues

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ROLE OF PRESCRIBED FIRE IN WILDERNESS

Group A. Discussion Report
Issue Leader, Michael J. Rogers
Issue Reporter, Gene W. Benedict

INTRODUCTION

Concern over the U. S. Department of Agriculture, Forest Service's proposal for using planned ignitions in wilderness surfaced in work group discussions which followed the Wilderness Fire Symposium held at the University of Montana November 15 through 18, 1983. These concerns focused on a variety of issues such as legal authority, public involvement, intra-agency and interagency coordination, agency philosophies, and confusion over existing and proposed agency policies.

On the last day of the Wilderness Fire Symposium, each symposium attendee was provided an opportunity to participate in one of four workshops which followed 3 full days of formal presentations by management and research subject matter specialists. This paper summarizes the contributions of 200 or more persons who participated in a subsequent brainstorming session. Every workshop participant who wanted to identify an issue, express a concern, or make a brief statement had an opportunity to do so. A notetaker attempted to capture the essence of each person's statement on a flip chart. To verify the accuracy of the written statement, the workshop notetaker read the statement aloud. Statements were modified until they accurately reflected the thought the speaker wanted to convey. After all participants had an opportunity to express themselves, the entire group identified the following five broad categories into which statements could be classified: Philosophical, political, technical, legal-policy, and administrative-management. The group then reviewed each statement, and the person responsible for the statement had one last opportunity to modify his or her statement and assign it to one of the five categories. When possible, like comments were grouped and further developed into one or more recommendations by the authors.

Paper presented at the Wilderness Fire Symposium, Missoula, Mont., November 15-18, 1983.

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PHILOSOPHICAL CONCERNS

-- What does the use of planned ignitions to perpetuate wilderness resources mean? A potential for misunderstanding exists.

-- We need to recognize and evaluate modern human impacts on wilderness (for example the introduction of wildlife species), which are assumed to be a natural part of wilderness.

-- We need to consider dilemmas that have developed over the wilderness concept. For example, how do newer wilderness areas (such as eastern and urban wilderness) relate to the original wilderness concepts envisioned in the 1964 act?

-- We need to resolve the issue of whether to restore processes which existed in wilderness before human intervention or whether to strive for an equilibrium based on what we now have.

-- We need to consider the holistic concept of wilderness that encompasses its combined sociological/biological/economic/political/physical aspects, not just its individual components.

-- How can we be concerned about justifying the use of planned ignitions in wilderness in view of other permitted manipulative uses such as livestock grazing and mining?

-- Scientists seem unwilling to listen to another point of view--the wilderness perspective as defined by the Act.

Recommendation:

Develop an agency position that establishes a baseline for "what wilderness is"; that is, is wilderness what exists today, or is it what we had before human intervention through such activities as fire suppression?

POLITICAL CONCERNS

-- We are moving too far, too fast toward planned ignitions without adequate debate.

-- We need to address the potential political ramifications of planned ignitions in wilderness by developing a national, interagency public relations effort.

-- Will the use of planned ignitions adversely affect the credibility of existing wilderness fire management programs?

-- How do we coordinate the goals of maintaining "natural" processes, especially in view of the ever-changing world ecosystem, and achieving what the public really wants, particularly if their desires do not fit the natural concept of wilderness?

-- There is too much emphasis on the physical aspects of wilderness and not enough emphasis on the sociopolitical aspects.

-- There is not enough attention paid to what the public wants from wilderness management.

Recommendations:

1. Explain to agency employees the need for a policy change to permit the use of planned ignitions in wilderness before proceeding with public involvement.

2. After completing step 1, communicate with the public through involve-and-inform workshops before using planned ignitions within wilderness.

TECHNICAL CONCERNS

-- What effects do wilderness fires have on park or wilderness backcountry use or users? Will the use of fire in wilderness force traditional wilderness uses to change and subsequently impact other, nonwilderness, areas?

-- We need to address long-term smoke management problems in relation to prescribed fire and absence of prescribed fire.

-- We need to identify natural background outputs such as smoke and sediment production in wilderness.

-- There is a need for technology transfer of the wealth of current fire effects and fire ecology information to wilderness managers.

-- There is a problem with the equation: Unnatural Fuel Loading + Unnatural Ignitions = Natural Situation.

-- There is too much emphasis on fire frequency and not enough on fire severity.

Recommendation:

The use of prescribed fire requires additional monitoring, basic research, and technology transfer. These activities should focus on planned and unplanned ignitions at various intensity levels in wilderness and should include on-site and off-site effects.

LEGAL/POLICY QUESTIONS

-- We need to evaluate the impacts of unplanned human-caused ignitions, especially if they meet predetermined management objectives.

-- We need to be consistent in all aspects of wilderness management. For example, if we don't allow planned ignitions, why allow mining and grazing which are not natural?

-- Does the Wilderness Act give the authority to trammel the wilderness by suppressing fire?

-- Does the Wilderness Act authorize the Forest Service to use planned ignitions in wilderness for any purpose?

-- We need to consider the contradictions of eastern and urban wilderness as they relate to the wilderness concept envisioned in the 1964 Act.

-- There is concern about inconsistency between agencies on policies for using planned ignitions in designated wildernesses: the U.S. Department of the Interior, National Park Service, has wilderness areas designated under the 1964 Wilderness Act and they use planned ignitions; the Forest Service does not yet use planned ignitions in designated wilderness areas.

Recommendation:

Determine whether the Forest Service has the authority under the Wilderness Act to authorize the use of planned ignitions in wilderness for the purpose of restoring natural processes.

ADMINISTRATIVE/MANAGEMENT CONCERNS, GROUP I

-- Lots of energy seems to have been expended to come up with one set of criteria for justifying the use of planned ignitions for all wildernesses without recognizing the uniqueness of each wilderness.

-- Proponents of planned ignitions in wilderness must have a clear understanding of the Wilderness Act and agency policy.

-- Will fire plans that do not allow for planned ignitions cause fires of unnatural size and intensity along boundaries, thus making escape of fires from unplanned ignitions highly probable?

-- We too often seem to use "unnatural fuel buildups" to justify fire, even though suppression actions have only been effective for 30 to 40 years.

-- There is too much emphasis on fire management and not enough emphasis on fire nonmanagement, that is, the long-term losses of not managing fire.

-- We fail to recognize in the current land management planning process that mitigation measures may be required, based on past and future suppression actions in wilderness areas.

-- There is a need to emphasize fire suppression as an act of manipulation, as well as human-induced ignitions as acts of manipulation.

-- Management needs to become more knowledgable about current research on ecology/ecosystem dynamics.

-- If prescribed fire is to be used in wilderness, its need and purpose should be clearly identified, be site specific, understood, and monitored.

Recommendations:

1. All line officers making management decisions about prescribed fire in wilderness from planned or unplanned ignitions must fully comprehend the Wilderness Act, subsequent wilderness legislation, and agency wilderness policy.

2. If the uniqueness of each wilderness area is to be respected, each decision to use prescribed fire in wilderness should be made on a case-by-case basis.

ADMINISTRATIVE/MANAGEMENT CONCERNS, GROUP II

-- Our consideration of wilderness should include wildlife needs, especially threatened and endangered species such as the grizzly bear.

-- Are we using wilderness values to accomplish a hidden agenda not based on such values, for example, in providing more elk habitat?

Recommendation:

Conflicts between the Threatened and Endangered Species Act and the Wilderness Act, subsequent wilderness legislation, and agency wilderness policy should be resolved on a case-by-case basis if conflicts arise.

ADMINISTRATIVE/MANAGEMENT CONCERNS, GROUP III

-- Use of planned ignitions in wilderness must be coordinated on an interagency and interregional basis with nonwilderness fire activity, resource availability, and air quality.

-- The increasing number of fire management plans that include unplanned ignitions has not been adequately addressed on a Regional basis. This may necessitate the suppression of some unplanned ignitions and use of planned ignitions in some wildernesses to spread out prescribed fire impacts over a greater period of time.

-- Prescribed fire using planned ignitions will be needed in wilderness to protect adjoining off-site values where there is physically no other way to protect adjoining off-site values because of land ownership patterns, special use improvements, or other problems.

-- Because of our suppression policies inside and outside wilderness, ecological change has been the same in both areas. Our priority should be to mitigate the effects of years of suppression outside wilderness.

-- We need to use planned ignitions outside and adjacent to wilderness boundaries rather than using planned ignitions inside wilderness, so that fire from unplanned ignitions can play their natural role within wilderness without threatening surrounding values.

Recommendations:

1. Planned ignitions inside and outside wilderness should complement each other. Planned ignitions should be used inside wilderness only when this use can be properly justified.

2. Planned and unplanned ignitions must be coordinated on an intra-agency and interagency basis.

ADMINISTRATIVE/MANAGEMENT CONCERNS, GROUP IV

-- We need to determine what types of funds can be used to carry out wilderness fire management programs.

-- Future economic analysis must consider the cost of restoring ecosystems that are unnatural because all fires have been suppressed.

-- Requiring the cost of wilderness fire management to be less than or equal to the present cost of wildfire suppression on that piece of land does not seem realistic. Better management through initial treatment with prescribed fire may be enough justification for its use, costs aside.

Recommendations

1. Existing Forest Service policy on how wilderness fire management programs will be funded needs to be clarified.

2. Analysis of potential prescribed fire programs using planned ignitions should include a careful examination of trade-offs. For example, a policy of total fire suppression may appear to be more cost-effective in the short run; however, higher initial costs of a proposed prescribed fire program may be much more cost-effective in the long run.

ADMINISTRATIVE/MANAGEMENT CONCERNS, GROUP V

-- Does the prescription for planned/unplanned ignitions in wilderness cover all phases of the prescribed fire from start to finish?

-- The public's perception of our credibility in conducting a wilderness fire management program will be based on the actions of the least qualified individual.

-- Fire and wildlife managers/specialists have forced a debate on the wilderness fire management issue. Wilderness specialists must be clear about their philosophy and practices if they are to effectively debate the issues.

-- We must clear up the public's confusion over Smokey's message. Smokey needs to differentiate between prescribed fire and wildfire.

-- We need to clarify the terminology used in describing wilderness fire management programs, that is, unplanned ignitions versus unscheduled ignitions.

Recommendations:

1. Wilderness fire prescriptions must be prepared and conducted by qualified fire and wilderness management professionals.

2. Standardize the terminology used to describe wilderness fire management programs.

The concerns raised in the workshop will be sent on to the USDA Forest Service, Recreation Management and Aviation and Fire Management Washington Office staffs, where they can be fully considered as the Forest Service continues to deliberate the possibility of using planned ignitions in some wilderness areas.

ROLE OF INDIAN BURNING IN WILDERNESS FIRE PLANNING

Group B. Discussion Report
Issue Leader, John G. Dennis
Issue Reporter, Roland H. Wauer

INTRODUCTION

The concept of wilderness incorporates the notions "primordeal" and "natural" into management of relatively large and undisturbed blocks of land. In recent years, the role of lightning as a cause of fire and the adaptations of plants, animals, and entire communities to fire have become well enough understood to make it clear that fire can play a natural role in ecosystems. At the same time, it has become equally clear that humans have initiated many fires, which because of their human origin may not be considered natural. This uncertainty about the status of human-caused fire creates difficulties for wilderness management.

The dilemma becomes more acute when the comparative fire-ignition roles of Native Americans and Euroamericans are considered. For thousands of years, Native Americans totally depended on the natural ecosystems in which they found themselves. Although they were a part of these ecosystems, they learned to modify and influence them through the deliberate use of fire. Euroamericans, on the other hand, went well beyond the minor modification of ecosystems; in many cases, they completely changed the natural ecosystems, in part through the total suppression of fire.

Even though Indian fires did not dramatically alter the ecosystems in which Indians lived, evaluating the effects of such fires presents a dilemma for the wilderness manager: Are the Native American-caused fires natural and thus do they need to be restored to presuppression frequencies? Or are they a human-caused, unnatural disturbance that must be factored out of any modern fire prescription based on fire history data?

Four contributors to this Symposium (Gruell, Lewis, Arno and Phillips) examine the role of Indians (Native Americans) in the fire history of North American ecosystems. Their papers make it clear that Indians deliberately burned for a variety of purposes, including signaling, food gathering, hunting, forage and animal population management, vegetation management, maintenance of habitat diversity, and warfare. These authors make it equally clear that Indians used fire in different frequencies, intensities, locations, and seasons, and that as a result of this diversity the effects of Indian fire regimes varied greatly across North America.

In a fifth Symposium paper Kilgore sought to define what is natural. In developing a definition of natural, he learned that views on naturalness of fire in North America range from those stressing the absence of any human intervention, to others stressing the intrinsic attributes of fire almost regardless of the agent of ignition, to yet others stressing only those fires characteristic of pre-European time, whether caused by lightning, volcanoes, or Indians. Drawing on this information base, Kilgore concluded that a natural fire includes the processes and the effects that would occur in the absence of technological humans. Such a definition includes Indian burning as part of the natural fire regime.

WORKSHOP PROCEDURE

The information and philosophical challenge presented by these five papers drew between 30 and 40 conference attendees to participate in a 2½-hour workshop on Indian burning. Discussion began with a listing of possible topics, continued with in-depth discussion of key topics, and ended with consensus on and a summary of principal conclusions.

Topic Identification

The workshop moderator opened by presenting questions drawn from the speakers' presentations. These questions asked:

1. whether the Indian population ever was large enough to have had a significant impact on North American ecosystems;

2. whether good data exist about what Indian burning occurred in which ecosystems;

Paper presented at the Wilderness Fire Symposium, Missoula, Mont., November 15-18, 1983.

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3. whether, when, and where Indians burned over large areas of land;

4. whether Indian burning affected species evolution, relative abundance of vegetation types, soil erosion, or relative shifts in animal species abundance;

5. whether Indians deliberately burned to maintain ecosystems diversity and, if so, whether modern land managers should burn to create or maintain diversity, especially in small or isolated parks and wildernesses; and

6. whether Indian burning should be considered natural.

Workshop participants added topics dealing with:

1. phases of fire in North America (prehuman, Indian, contact/pioneer, early modern with emphasis on control, and modern with emphasis on management);

2. the concern that simulating past Indian burning may merely maintain an artifact of past cultures, not meet a management goal relevant to today's policies;

3. the kinds of evidence needed to demonstrate the presence, extent, timing, and effects of past Indian burning and whether such evidence can be distinguished from evidence of lightning ignitions;

4. the value, if any, of perpetuating known Indian burning regimes if it can be shown that such burning had no significant ecosystem impact;

5. the possibility that a hidden agenda motivates those urging simulation of Indian burning because they believe it is easier to manage many little fires than a few conflagrations;

6. a need to obtain facts before making management decisions;

7. a concern that managing to achieve "Indian fires" may be contrary to, or an affront to, desires of modern Indians;

8. the usefulness of determining the existence of information sources that provide evidence about Indian burning;

9. the value of investigating existing traditional aboriginal burning practices in other coutries to improve our knowledge of traditions, techniques, and expected results associated with those practices on the assumption that reasons for burning today are similar to reasons for burning in the past; and

10. the need to differentiate between research (learning whether we can restore Indian burning) and policy (deciding whether we want to restore Indian burning) assuming we learn to do so.

Drawing from this diverse list of topics, workshop participants focused on three generic, but critical, subjects:

1. availability and value of information sources;

2. probable patterns and effects of Indian burning; and

3. purposes to be achieved by simulating Indian burning.

Topic Discussion

Availability and Value of Information Sources.--This topic was recognized as central because information about past Indian burning must play a fundamental role in future decisions to simulate such burning. The participants concluded that, although not all types of information are available for every region of North America, it is highly probable that at least some Indian burning occurred in most or all of the major North American ecosystems and that at least some information is available for each area of burning. The major identified sources of such information include technical literature; historical literature; Indian descendents; pioneer descendents; unpublished information from anthropologists and other cultural specialists; fire scar studies; palynological and charcoal studies; vegetation stand structure analyses; Indian population density, chronology, site, and corridors of use determinations; comparative cultural studies; plant opal occurrence and abundance studies; and ethnobotanical investigations.

Probable Patterns and Effects of Indian Burning.--This topic was considered critical because the patterns and effects of Indian burning are significant in management planning and decision-making. Significant points developed by the participants included:

1. the need to be aware of both patterns (spatial and temporal) and effects (short-term versus long-term) of Indian burning;

2. a realization that inference will be an important and integral part of any findings made about the role of Indian burnings;

3. a recognition that the intensity of effects of Indian burning varied in time, in space, and with ecosystem type;

4. an awareness that Indian burning was not simple or random, but was localized and often deliberate and thus exerted a complex influence on development of local vegetation and ecosystems and on maintenance of diversity in those systems; and

5. a caution that Indian burning practices may have changed markedly after first contact between Indians and Europeans because of Indian population declines due to European diseases and Indian use of fire to fight the advancing Europeans.

Purposes of Simulating Indian Burning.--Participants identified three major areas requiring further consideration:

1. whether, by definition, human influence is absent in wilderness, and, if so, whether only natural ignitions are acceptable;

2. whether some wilderness areas should be managed as simulations or vignettes of Indian or early pioneer landscapes typical of the regions containing the wilderness areas; and

3. whether the impacts of modern humans outside wilderness areas are so detrimental that wilderness or other natural areas (including research natural areas) should be managed aggressively through use of fire to maximize the diversity and hence the probability of long-term survival of biota and communities found within them.

CONCLUSIONS

Because of a lack of consensus on how to interpret the Wilderness Act, and thus on whether to include the past role of Indian burning in wilderness management, all participants agreed that further development of philosophy and policy is required to support future decisions about the role of Indian burning in wilderness management. From a technical standpoint, as a result of their identification and discussion of the topics mentioned here, workshop participants reached consensus on the following conclusions:

1. Fire history data actually or potentially are available for most areas of North America; these data enable managers to decide what degree of past human-caused fire influence to include in modern management of any given area.

2. Once fire history information is available, it will be possible for managers to create any desired scenes, processes, or effects that would have existed had Indian burning remained a part of the management area.

3. It is possible to use information about the role of Indian burning in natural systems to guide decision-making on how to manage today's wildernesses in achieving, for example, maximum diversity or preservation of successional communities.

4. Because wilderness areas are unique and their management needs are specific to their individual locations, managers should not adopt a blanket policy regarding Indian burning that would override the site-specific characteristics and needs of individual areas.

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WHAT INFORMATION IS NEEDED FOR WILDERNESS FIRE MANAGEMENT? //

Group C. Discussion Report
Issue Leader, Boyd Evison
Issue Reporter, Peter J. Roussopoulos

In a workshop allotted 2½ hours, roughly 75 individuals, only slightly acquainted, and representing a wide variety of public, private, and academic institutions and organizations, sought common ground and acceptable conclusions regarding information needs for fire management in legislatively designated wilderness. Consensus was not attained; but several strong concerns held in common were identified, and some generally accepted principles were recognized. A summary and brief discussion of the group's deliberations follow.

WORKSHOP ORGANIZATION

The group discussion began with an open, brainstorming session to establish a set of categories of fire management activities to reduce to more manageable units those factors generating information needs. Five fire management categories were established; and five discussion groups were organized, by category, to identify the kinds, quantity, and quality of information needed in dealing with decisions and actions vis-a-vis each of those categories. Discussion group findings were reviewed by the full working group before the overall proceedings were reported to the symposium's general assembly.

The categories established by the full working group were:

1. establishing objectives for a wilderness fire management program;

2. predicting and assessing fire behavior and burn characteristics for any given ignition;

3. determining whether predicted or known fire behavior is consistent with established objectives;

4. choosing a management strategy for an individual fire; and

5. monitoring and evaluating results to determine what else is needed to accomplish program objectives.

General results of the working group's deliberation are summarized in table 1. The Arabic numerals across the top correspond to the activity categories listed above. The column of X's below each numeral identifies the general categories of information desired or useful in performing the activity denoted. These perceived information needs represent an aggregation of views, rather than consensus.

DISCUSSION

Several papers offered at the symposium (e.g., those by Parsons and others; Bonnicksen; Kilgore; Mills; and Van Wagner) emphasized the need to identify explicitly the goals and objectives of fire management in wilderness, as well as those of wilderness management itself. There is a need to:

1. recognize differences in the basic roles and purposes of wilderness-managing agencies, as framed by their organic legislation, affected by policy and public perceptions, and further detailed by the National Wilderness Preservation System Act;

2. identify the points on which wilderness fire management goals, objectives and methods coincide; and

3. recognize those points on which they cannot coincide.

The divergent views among group participants originate from different perceptions of the meaning of wilderness. Among those for whom "wilderness management" is an oxymoron, the view is that all natural fire should be allowed to burn without intervention, except perhaps where it threatens lives or property beyond wilderness boundaries. Manipulation of wilderness ecosystems, by fire or other means, is abhorred, even if to compensate for the effects of past (or unavoidable contemporary) interference by technological humankind. For the purposes of those espousing this perception, relatively little fire management information would be needed, other than that which is necessary to keep fires from threatening lives or property.

Paper presented at the Wilderness Fire Symposium, Missoula, Mont., November 15-18, 1983.

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Table 1.--Applicability of various kinds of information to five broad categories of fire management activity

General Information Category	Activity Category (see text) 1	2	3	4	5
Biological					
Current and historical ecosystem states	X		X		X
"Natural" or desired ecosystem state	X				X
Ecosystem dynamics	X		X		X
Biological effects of fire	X		X	X	X
Biological effects of fire management actions	X			X	X
Physical					
Historical fire regime	X				X
Fuelbed characteristics	X	X	X	X	X
Developments and cultural resources	X			X	X
Weather/climate (current, historical, and prehistoric)	X	X	X	X	X
Terrain	X	X	X	X	X
Soil characteristics		X	X	X	
Physical effects of fire	X		X	X	X
Physical effects of fire management actions	X			X	X
Fire behavior characteristics	X		X	X	X
Social					
Public preferences and perceptions	X		X	X	X
Resources use patterns	X		X	X	X
Local demography	X		X	X	X
Public safety risks	X		X	X	X
Political					
Wilderness laws and regulations	X			X	X
Environmental laws and regulations	X			X	X
Agency policies implementing applicable laws	X			X	X
Laws establishing area and its purpose	X				X
Agency purposes (as in its Organic Act)	X				X
Economics					
Resource value changes					
- associated with fire	X			X	X
- associated with fire management actions	X			X	X
Costs of fire management actions	X			X	X
Operational					
Quantifiable program objectives			X	X	X
Management objectives and practices on adjacent lands	X			X	X
Availability of fire management resources				X	
Effectiveness of fire management actions		X		X	

A more complex view is held by those who would restore ecosystem structures and/or processes to those that probably existed had there been no disruption of natural processes by technological humankind. Among this group there are some who are more concerned with structure than with process, particularly as such structure relates to the re-creation of a given scene. Others feel that natural processes such as fires will restore natural conditions. These people focus primarily on process, rather than structure. They would take whatever measures are necessary to ameliorate the unnatural situations. For example, they would burn fuel accumulation developed as a result of many years of fire protection. Further, they would attempt to compensate for the absence of vast catastrophic fires in wilderness and prevent the extension of such fires outside of wilderness. Recognizing that natural fires are an integral part of the dynamics of natural ecosystems, the long-range goal of both of these groups would be to let natural fires burn naturally.

The information needs of those involved with manipulation are considerably greater than those of the "laissez-faire" group. Those who believe that true naturalness can be achieved only by careful reconstruction of the structure of

ecosystems as they existed at the moment in history when technological men arrived on the scene require information in considerable detail and accuracy. This task is complicated by the human tendency to alter first and observe/record afterward. Those who would simply eliminate "unnatural" threats may need less information. They would let natural fires burn with only such intervention as may be needed to prevent catastrophe. The faith of these people in the long-term efficacy of natural fire in restoring natural processes (and scenes) is more obvious but no less real that is the faith of the reconstructionist in their ability to describe and reconstruct ecosystem structure of the past, probably with greater accuracy. In either case, an approximation of the desired state is the best that can be achieved. The cost of achieving it may differ significantly.

Recognition of the fact that the best that can be achieved is only an approximation of a naturally functioning ecosystem unaltered by technological man seems to be a key to resolving the issue. There are places in which it is appropriate to attempt restoration of historical ecosystems structure, either mechanically or with fire; but it should be understood that no miracles of silicon-assisted computation can ever be expected to factor out all of the effects of climatic cycles, widely present contemporary or historical anthropogens, or current differential effects of the introduction or loss of domestic or native biota. There is also a high probability of gaps in any historical picture. Furthermore, the practicality of either approach varies substantially with the nature of the particular ecosystems involved. It is highly likely, for example, that in the many thousands of years of the existence of the giant sequoia forests of the southern Sierra conditions much like those found today occurred naturally, at one time or another. So, except in such "showcase" areas (e.g., the Sherman Tree and environs) as may be managed to re-create and maintain an approximation of the scene as first seen by those who followed the arrival of "Indians" in the area, a predominantly laissez-faire approach may be appropriate. This may be tempered, to some extent, by concern for the relatively small total size of the remnant now protected--a concern that may persuade managers to engage in some form of protective manipulation beyond "showcase" areas, as well.

Regardless of the prevailing philosophy, wilderness fire management practices are constrained by a number of factors. These include the need to protect public and private resources adjacent to wilderness areas; comply with statutory and policy direction; ensure the safety of visitors, local residents, and official personnel; stay within the constraints of State or other air and water quality regulations; and gain public understanding and support. Program objectives and practices must therefore consider protection of developments and cultural resources; safety and risks associated with resource use patterns and the density and distribution of nearby private holdings; applicable enabling legislation, wilderness and environmental laws, regulations, and policies; expected economic costs and benefits (both on- and off-site) of alternative programs; and resource management values and concerns on adjacent lands.

Knowledge of the physical factors affecting fire intensity and spread is most important in the manipulative uses of fire, in judging the risks associated with natural ignitions that may threaten lives or property, and in theorizing about the probably influence of prehistoric climatic conditions. Monitoring fire behavior and consequences increases one's ability to predict accurately future fire behavior and effects, and improves the effectiveness with which the outcome of natural processes and manipulative measures may be predicted.

CONCLUSIONS

The large diversity of information types and sources identified by the working group and represented in table 1 illustrates the highly complex nature of wilderness fire management decisions. Although the group compiled a long list of broad information categories that are useful in making such decisions, the group found it difficult to be specific about detailed requirements for desired data elements. The working group found it particularly frustrating to establish priorities for collecting information on various management activities.

The need for information is governed largely by the nature of management objectives, the latitude afforded fire management decisionmakers, and uncertainties characterizing different fire situations. Further, these factors are greatly affected by prevailing philosophies of wilderness--for which there are several possibilities. Given such a wide diversity of wilderness fire management contexts, it is not surprising that a consensus on generalized information requirements was not attained. Furthermore, the group raised serious questions about the ultimate worth of any generalization about wilderness fire management information requirements. Perhaps information management for wilderness fire decisionmakers will remain, as it has for many emergency services, an issue most appropriately addressed on a decision-specific or case-by-case basis.

THE HIGH-INTENSITY AND LARGE-FIRE ISSUE IN WILDERNESS

Group D. Discussion Report
Issue Leader, Douglas Bird
Issue Reporter, Robert C. Lucas

The large, active group that discussed the issue of high-intensity and large fires in wilderness agreed that such fires will occur in the future, whether they are wildfires or prescription fires. They agreed further that, in some areas at least, such fires are appropriate because they are important natural events that have been instrumental in the dynamic processes shaping many wilderness ecosystems. Although some high-intensity and large fires are ecologically appropriate, they are nevertheless unacceptable because of their excessive costs and risks.

The major limiting factors that make some of these fires unacceptable can be usefully considered in terms of the decision space pentagon presented earlier at this symposium by Orville Daniels. The five limiting factors in this concept are social, political, economic, physical and biological. All five must be considered in dealing with the high-intensity and large-fire issue because there are specific, critical problems under each heading, any of which can be the limiting factor in a particular situation. In general, however, the group felt that social, political, and economic factors usually dominate, and the larger or more intense the fire, the more dominant these factors become.

The specific problems identified as most likely to be critical constraints were smoke, spread of fire outside the wilderness, and downstream effects (in essence, another form of spread outside the wilderness to areas with different objectives and values). Although safety was mentioned only briefly as an issue in the group discussions, we would add it to the list.

Paper presented at the Wilderness Fire Symposium, Missoula, Mont., November 15-18, 1983.

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Numerous concerns were raised. Some of these concerns were:

1. Could high-intensity and large fires endanger the present wilderness fire management program by exceeding the tolerance level of key publics?

2. Could high-intensity, large prescription fires, at least in National Forest wilderness, exceed budgets in the benefiting functions (such as the wildlife and recreation functions), and thus preclude further prescribed wilderness fires? (Dollars are limiting.)

3. Should wilderness fire management plans extend beyond wilderness boundaries if high-intensity, large wilderness fires are to be dealt with adequately? Fuel reduction buffers, preferably outside the wilderness boundary, were suggested. Land management planning might be a useful vehicle for dealing with the possibility of the spread of fire outside wilderness boundaries.

4. Is there an increased risk of invasion of exotic plants, some of which have light, widely dispersed seeds, in areas burned by large, high-intensity fires that may severely reduce local seed sources and vegetative reproductive organisms?

5. It is important to adhere to approved wilderness fire plans. Managers must have the commitment to follow the plan and not be tempted to improvise or second-guess.

6. The public will be less tolerant of smoke and other adverse effects of a fire burning under prescription, especially a large, high-intensity fire, than of a wildfire that managers are attempting to suppress. The wildfire is considered an "act of God," in a sense, whereas the prescription fire is the manager's responsibility.

7. Social acceptability of high-intensity, large fires will depend critically on a high level of technical competency by managers, and the least competent manager may determine the credibility of the program.

8. Management policies for high-intensity, large fires should be tailored to fit varying local conditions, not applied inflexibly over widespread wilderness systems.

Several recommendations came out of the group discussions:

1. Concentrate on building understanding of wilderness fire with affected publics. The group felt this was the top priority, and the better it was done, the less problem there would be later with political and economic factors. It was felt that education/involvement efforts need to be targeted at specific publics. (Someone said, "We need to know who the players are, and the level of understanding and tolerance for wilderness fire of each player.") For example, it was suggested that local residents require one education/ involvement approach, whereas nonlocal visitors require a different approach.

2. Increase research directed at improving long-term predictability of behavior of long-burning fires. This need was labeled "seasonal severity index" and related to the difficulty of predicting what an early season fire may do a month or two later, depending on the type of fire season that develops.

3. Establish a clearinghouse or procedure for the exchange of wilderness fire management plans and supporting information. It was pointed out that Bill Fischer of the Northern Forest Fire Laboratory has been performing much of this function effectively.

4. Build more within-agency understanding and support for wilderness fire management by encouraging persons not normally involved to have direct, hands-on experience with wilderness fires, perhaps for 3 to 5 days. The resulting improved employee understanding could strengthen public education and help build support.

5. Continue to strive for common terminology for wilderness fire management.

Section 10. Poster Papers and Abstracts

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"BEHAVE" IN THE WILDERNESS! [1]

Patricia L. Andrews and Robert E. Burgan

ABSTRACT: The BEHAVE system for fire behavior prediction and fuel modeling is a set of interactive computer programs that can be used whenever site-specific fire behavior assessment is needed. BEHAVE is applicable to wilderness fire management for prescription development and to predictions of the behavior of a specific fire. This paper describes the fire behavior predictions that are available from BEHAVE and the process of building a custom fuel model. Example output from the programs is given.

INTRODUCTION

BEHAVE is a fire behavior prediction and fuel modeling system consisting of a set of interactive, user-friendly computer programs that are designed for use by fire practitioners (Andrews 1983). BEHAVE can be used whenever site-specific fire behavior assessment is needed, as in real-time fire behavior prediction, prescribed fire planning, fire gaming, training, initial attack dispatch, and wilderness fire management. As stated in the "Wilderness Fire Management Planning Guide" (Fischer, in preparation), one of the questions that an adequate evaluation of fire potential will answer is "How might the various fuels burn under a range of likely weather conditions?" BEHAVE is ideally suited to this task. Other specific applications for wilderness and park fire management include gaming historical fires to determine potential fire size for use in prescription development, daily projection of the growth of a going fire, and estimating potential for spot fires occurring outside the management area.

The BEHAVE system overcomes what have been significant limitations to fire behavior prediction by adding an improved fine fuel moisture model (Rothermel, in preparation) and methods for building site-specific fuel models. Since fuel modeling is a major activity, quite separate from operational fire behavior prediction, the BEHAVE system is divided into two subsystems (Andrews, in preparation; Burgan and Rothermel, in preparation). It is likely that a specialist will build fuel models to be used by a larger group of people. In some cases, after an initial effort to develop fuel models for a management area, only the fire behavior prediction part of BEHAVE will be used.

FIRE BEHAVIOR PREDICTION

Some of the fire prediction capabilities BEHAVE offers have been available previously in the form of tables, graphs, nomograms, hand-held calculators, and other computer programs. In addition, new fire behavior technology, based on recently developed mathematical models, is presented for the first time. Thus, BEHAVE gathers state-of-the-art fire behavior prediction technology into a single, easy-to-use package. As new fire prediction models become available, they will be added to the system.

Aspects of fire behavior that can be predicted by BEHAVE include:

- Direction of maximum spread under cross-slope wind conditions.
- Rate of spread, either in the direction of maximum spread or in any other specified direction.
- Flame length, fireline intensity, and effective windspeed in the direction for which the rate of spread was calculated.
- Heat per unit area and reaction intensity.
- Area, perimeter, and length-to-width ratio for a fire that started from a point source.
- Line building rate required to contain a spot fire at a specified size.
- Final size of a spot fire that is contained by a fireline built at a specified rate.
- Maximum spotting distance from torching trees, a burning pile, or a spreading surface fire.
- Probability of ignition.
- The moisture of fine dead fuels, given specific environmental conditions.

Output can be in the form of a single calculation, a list, or a table (figs. 1 to 3). Table output is ideally suited for "what-if" questions pertaining to wilderness and park fire management. This includes both before-the-fact predictions used in defining prescriptions and post-ignition predictions to estimate what a specific fire will do. Wilderness and park fires are especially well suited to the real-time fire behavior prediction techniques described by Rothermel (1983) because they are not normally "hampered" by suppression action.

[1] Paper presented at the Wilderness Fire Symposium, Missoula, Mont., November 15-18, 1983.

Patricia L. Andrews is a mathematician, Intermountain Forest and Range Experiment Station, USDA Forest Service, Missoula, Mont.; Robert E. Burgan is a research forester, Intermountain Forest and Range Experiment Station, USDA Forest Service, Missoula, Mont.

Input

```
1--FUEL MODEL                         12 — MEDIUM LOGGING SLASH
2--1-HR FUEL MOISTURE, %              6.0
3--10-HR FUEL MOISTURE, %             7.0
4--100-HR FUEL MOISTURE, %            7.0
7--MIDFLAME WINDSPEED, MPH            5.0
8--PERCENT SLOPE                      10.0
9--DIRECTION OF WIND VECTOR           0.0
     DEGREES CLOCKWISE
      FROM UPHILL
10--DIRECTION OF SPREAD               0.0  (DIRECTION OF MAX SPREAD)
    CALCULATIONS
     DEGREES CLOCKWISE
      FROM UPHILL
```

Output

```
RATE OF SPREAD, CH/H-----------     14.
HEAT PER UNIT AREA, BTU/SQ.FT--   2281.
FIRELINE INTENSITY, BTU/FT/S---    605.
FLAME LENGTH, FT---------------      8.6
REACTION INTENSITY, BTU/SQ.FT/M  6799.
EFFECTIVE WINDSPEED, MPH-------      5.1
```

Figure 1.--Example input and output from the operational fire behavior prediction part of BEHAVE.

1-HR MOIS (%)	RATE OF SPREAD (CH/H)	HEAT PER UNIT AREA (BTU/SQ.FT)	FIRELINE INTENSITY (BTU/FT/S)	FLAME LENGTH (FT)	REACTION INTENSITY (BTU/SQFT/M)	EFFECT. WIND (MPH)
2.	19.	2651.	909.	10.3	7902.	5.1
4.	16.	2375.	679.	9.0	7080.	5.1
6.	14.	2210.	550.	8.2	6587.	5.1
8.	12.	2121.	475.	7.7	6324.	5.1
10.	11.	2076.	429.	7.3	6189.	5.1
12.	10.	2041.	392.	7.0	6083.	5.1
14.	10.	1982.	351.	6.7	5907.	5.1

Figure 2.--Example of list output from the operational fire behavior prediction part of BEHAVE. In this case, calculations were made for a range of values for 1-hour fuel moisture.

FLAME LENGTH, FT

1-HR MOIS (%)	MIDFLAME WIND, MPH 0.	1.	2.	3.	4.	5.	6.
2.	3.9	5.6	7.0	8.2	9.3	10.3	11.2
4.	3.4	4.9	6.1	7.2	8.2	9.0	9.0
6.	3.1	4.4	5.6	6.5	7.4	8.2	8.9
8.	2.9	4.1	5.2	6.1	6.9	7.7	8.3
10.	2.7	3.9	5.0	5.8	6.6	7.3	8.0
12.	2.6	3.8	4.8	5.6	6.3	7.0	7.6
14.	2.5	3.6	4.5	5.3	6.0	6.7	7.3

Figure 3.--Example table output from the operational fire behavior prediction part of BEHAVE. In this case, flame length is predicted for a range of values for 1-hour fuel moisture and midflame windspeed. Conditions leading to a 4- to 8-foot flame length prediction are indicated.

FUEL MODELING

Stylized fuel models are used to describe various vegetation types as fuel complexes for fire behavior predictions computed in BEHAVE. Previously, there have been essentially 13 fuel models from which to choose. BEHAVE enables fire managers to design "custom" fuel models for specific vegetation types.

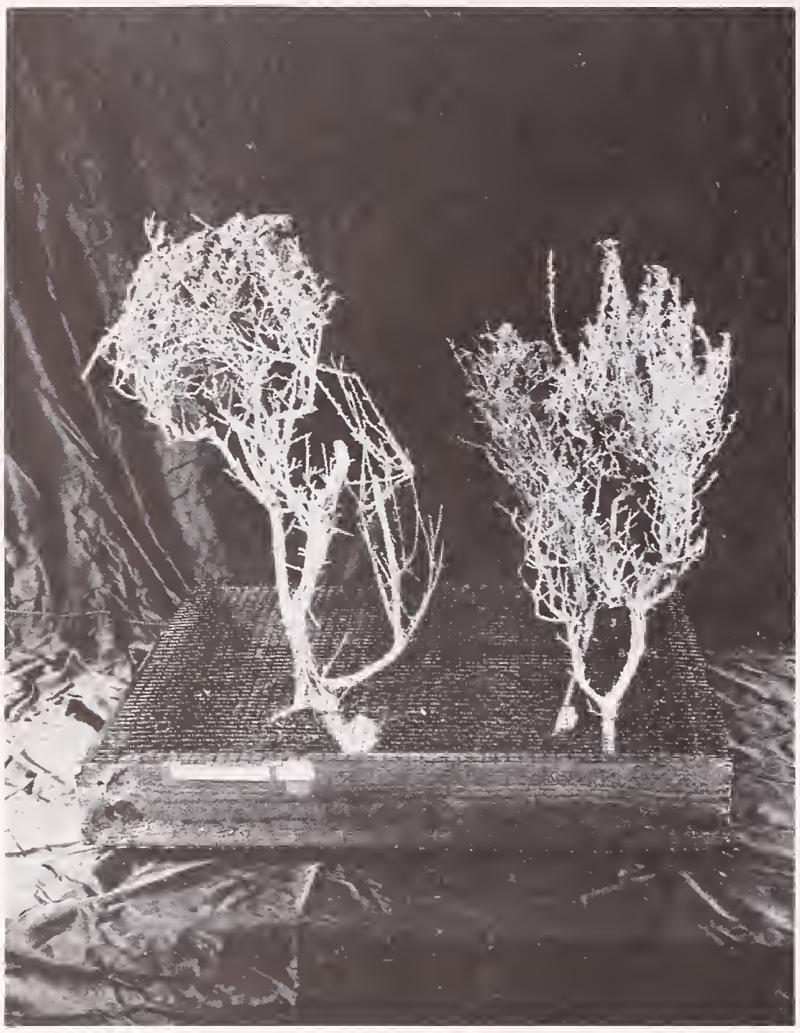
Although it is not necessary to develop a large number of fuel models to describe every vegetation type in a wilderness or National Park, it can be advantageous to build them for major fuel types (for example, bitterbrush on the Sierra Front [Rinehart, 1983], or bear clover in Yosemite National Park [van Wagtendonk, 1983]). On the other hand, if an area is very large or has many fuel types, it may be more feasible to build a fuel model after an ignition occurs (as in the Absaroka-Beartooth Wilderness [Keown, 1983]).

The field work required to build a fuel model is minimal. Data are collected for each component (grass, litter, shrubs, and slash) present in the fuel complex. Previously inventoried data can be used when it is available. Otherwise, estimates are based on visual estimates that can be made during a walk through the area. No rigorous inventory is required. For example, for an area containing shrubs, one option is to record shrub type and bulk density class from photos in the users' manual (fig. 4), estimate the percentage of fuel in each size class and the percentage of area covered by shrubs, and determine whether the leaves contain a significant quantity of oils and waxes. With these data, fuel load is estimated by the program. If the area also has grass, litter, or slash, similar data are recorded for these components. Contributions of the various fuel components are blended together by the program and a "first-cut" fuel model is proposed.

The next step is to test the fuel model over a range of environmental conditions. If a fuel type is common or critical enough to warrant a new fuel model to represent it, you will likely have some fire behavior observations that can be compared with predictions. At the very least you will have a feel for how fire behaves in that fuel complex. Output is presented in the form of tables or graphs (figs. 5, 6). Adjustments can be made to individual parameters of a fuel model after looking at the effect of a change on the predictions (fig. 7).

The process of building a custom fuel model is something of an art. It is definitely not a matter of collecting specific field data and having a data entry clerk type it into the computer. It is a job for the fire practitioner and takes both fire experience and an understanding of fire behavior prediction technology.

Once a fuel model has been built, it is stored in a file in the computer for later use. Custom fuel models can then be used for operational fire behavior prediction like the standard 13. It is only necessary to know its assigned number and the name of the file in which it is stored.



Shrub type 4, density 1

Shrub type 4, density 5

Figure 4.--Example photographs illustrating shrub type and density class. The photo series includes six density classes for each of four grass types and five shrub types.

FUEL MODEL TEST RUN -- USER DEFINED ENVIRONMENTAL INPUTS

STATIC 61. SAMPLE WILDERNESS MODEL BY: BURGAN

LOAD (T/AC)		S/V RATIOS		OTHER	
1 HR	1.62	1 HR	1728.	DEPTH	0.70
10 HR	4.00	LIVE HERB	0.	HEAT CONTENT	8000.
100 HR	7.20	LIVE WOODY	0.	EXT MOISTURE	28.
LIVE HERB	0.00	SIGMA	1417.	PR/OPR	2.99
LIVE WOODY	0.00				

ENVIRONMENTAL DATA	
1 HR FM	6.
10 HR FM	8.
100 HR FM	10.
LIVE HERB FM	150.
LIVE WOODY FM	150.
MIDFLAME WIND	4.

FIRE BEHAVIOR RESULTS

FIRE VARIABLE	SLOPE (%) 0.	10.	50.
ROS (FT/M)	3.	4.	5.
FL (FT)	2.	2.	3.
IR (BTU/SQFT/M)	2059.	2059.	2059.
H/A (BTU/SQFT)	558.	558.	558.
FLI (BTU/FT/SEC)	32.	33.	50.

Figure 5.--Example tabular output produced when using BEHAVE to develop a custom fuel model. The table gives values for the fuel model parameters and fire behavior predictions for a set of environmental conditions. In this case, three values have been assigned to slope, although any item in the environmental data list can be selected.

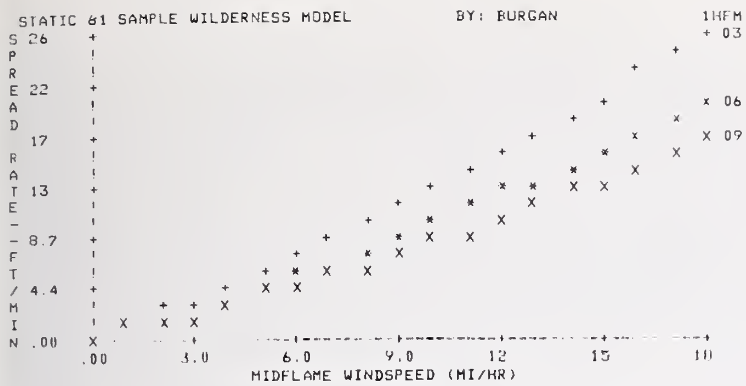


Figure 6.--Example graphical output produced when developing a custom fuel model. In this case, predicted rate of spread is examined for a range of windspeed and three 1-hour fuel moisture values.

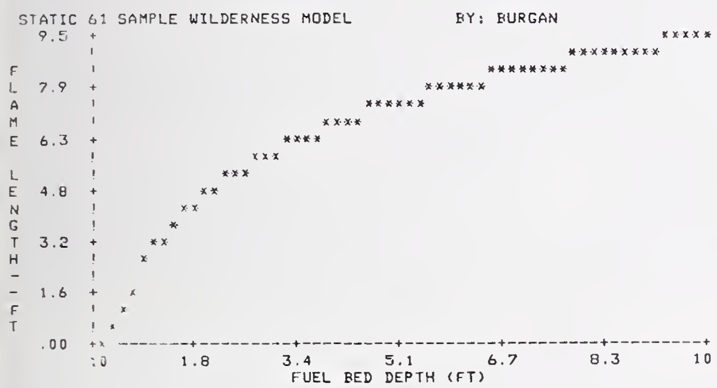


Figure 7.--Example graphical output showing the effect of a change in fuel bed depth on predicted flame length.

AVAILABILITY

A pilot test of the BEHAVE system has just been completed. Participants included personnel from the U.S. Department of Agriculture, Forest Service; U.S. Department of the Interior, National Park Service, Bureau of Land Management, and Bureau of Indian Affairs; and several States and universities. Based on feedback of these users, the programs, users' manuals, and training materials are being modified. The plan is to make BEHAVE available nationwide in 1984 with a system for maintenance and support of the programs. The BEHAVE programs are written in FORTRAN and can be easily transported to most minicomputers. Access to BEHAVE on local computers will make it available to a wide range of fire managers.

SUMMARY

The BEHAVE system enables a fire manager to design custom fuel models and to use state-of-the-art mathematical models to predict wildland fire behavior. BEHAVE is ideally suited for use in wilderness and park fire management activities.

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A PILOT STUDY OF VISITOR KNOWLEDGE AND SUPPORT FOR PRESCRIBED BURNING AT GRAND CANYON NATIONAL PARK[1]

John M. Baas, Glenn E. Haas, David M. Ross, and Ross J. Loomis

ABSTRACT: This study assessed visitors' knowledge and support for prescribed burning. We contrasted responses of those visitors who were aware of burning activities with those who were not and of those visitors who had received interpretive information about the purpose and value of prescribed burning at Grand Canyon National Park with those who had not. In May 1983, a questionnaire was given to a small sample of Park visitors. It was found that although visitors' knowledge about prescribed burning was low (an average of 49 percent correct answers), their support for a prescribed burning program was high (less than 14 percent disagreed). No statistically significant differences related to the awareness and information variables were found among visitors. The implications of these findings are discussed.

Natural resource managers are becoming increasingly aware and respectful of the human aspects of natural resource management. This positive trend will certainly be evident as prescribed burning increasingly becomes a key tool for natural resource management.

In a review of literature related to the fire/people interaction, Omi and Laven (1982) identified three reasons why public understanding and acceptance have lagged behind fire policy change and implementation: (1) overgeneralized interpretation of the Smokey Bear message, (2) the public's concern about and subsequent legislation related to air quality, and (3) the lack of consensus among resource managers regarding the use of fire. In addition to these reasons, the environmental movement of the 1960's and 1970's promulgated a widespread social philosophy that humans (thus managers) cannot improve a natural ecosystem and that wilderness management is synonymous with no management.

Stankey (1976) also found that wilderness visitors did not understand the use of fire in the Selway-Bitterroot Wilderness. Stankey queried 217 visitors using an 11-item fire knowledge test. Stankey found that the overall level of knowledge was poor (the average correct score was only 53 percent) and suggested that visitors should be educated about the role and value of prescribed fire in natural ecosystems.

At the request of Grand Canyon National Park officials and using the findings of Omi and Laven (1982) and Stankey (1976), we initiated a pilot study that had the following objectives:

1. To assess park visitors' knowledge and support for prescribed burning at Grand Canyon National Park.

2. To contrast the level of knowledge and support for prescribed burning between visitors who were subject to prescribed burning interpretive information and those whose were not.

3. To contrast the level of support for prescribed burning between visitors who were aware (through sight, smell, sound) of burning activities and those who were not.

METHODOLOGY

The study was designed to assess the effects of two variables on visitors' knowledge of prescribed burning and their support for it. The first variable was interpretive information about prescribed burning obtained through a campfire talk, an information flyer, or a discussion with a Park naturalist. The second variable was awareness obtained through seeing, smelling, or hearing about a prescribed burn while staying at Grand Canyon National Park. A two-factorial research

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Paper presented at the Wilderness Fire Symposium, Missoula, Mont., November 15-18, 1983.

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[1]A detailed description of the methodology and results is included in John Baas' Master's Thesis (Summer 1984), Department of Recreation Resources, Colorado State University, Fort Collins, Colo. 80523. This project was partially supported by C. S. U. project #53-1285.

design was used and consisted of four groups of visitors: (1) one group was subjected to only interpretive information, (2) one group to only burning activities, (3) one group to interpretive information and burning activities, and (4) one group to neither. Due to a small sample size, low response rate, and shortened prescribed burn program, it was not possible to fully implement the research design; therefore, this paper addresses only those aspects of the original design that could still be examined.

Sampling occurred from May 15 to May 25, when prescribed burning and associated interpretive activities took place. Every other visitor was given a questionnaire and asked to complete it after leaving Grand Canyon National Park; a postage-paid envelope was provided for its return.

The four-page questionnaire contained questions related to (1) visitors' knowledge of the role of prescribed burning, (2) their support for a prescribed burning policy, (3) their awareness of prescribed burning activities at the Park, and (4) the types of interpretive information obtained, if any, about prescribed burning while visiting the Park. These questions and answers are the basis of the findings in this report. Project funds did not permit sending follow-up questionnaires to visitors not responding to the initial distribution.

RESULTS

Of the 255 questionnaires distributed, 124 were returned. The overall response rate was 49 percent. The following results are categorized by objective.

Objective 1.--To assess park visitor knowledge and support for prescribed burning at Grand Canyon National Park.

Table 1 indicates the percentage of correct answers to the 11 questions pertaining to visitors' knowledge about prescribed burning. The percentage of correct answers was 49 percent, with more than 50 percent of all respondents correctly answering six questions. The questions most frequently missed related to fire impacts on plants and water quality; the role of lightning as an ignition source; and the impacts of cool, slow-moving fires versus hot, rapidly moving fires.

Table 2 indicates the level of support among all respondents for using prescribed fire. Slightly more than 65 percent of the respondents indicated they "strongly agreed" or "agreed" with the use of prescribed fire.

Objective 2.--To contrast the level of knowledge and support for prescribed burning between visitors who were subject to prescribed burning information and those who were not.

Table 1.--Percentages of correct answers by Grand Canyon National Park visitors by extent of interpretive information received.[1]

Questions	Visitor receipt of interpretive information: received[2] (n=47)	Visitor receipt of interpretive information: not received (n=77)	All respondents (n=124)
	- - - - Percent	- - - - -	
Forest fires are responsible for the kinds of plants found at or near the Grand Canyon.[3] (TRUE)	31	24	25
Forest fires can have beneficial effects on the natural environment of the Grand Canyon.[3] (TRUE)	75	74	74
The majority of fires at or near the Grand Canyon cover thousands of acres.[3] (FALSE)	47	48	48
The majority of fires at or near the Grand Canyon were started by lightning.[3] (TRUE)	26	25	25
Forest fires are often useful in providing minerals and nutrients for trees and plants.[3] (TRUE)	75	70	71
Most forest fires at or near the Grand Canyon result in the death of the majority of animals in that areas.[3] (FALSE)	67	60	64
Forest fires can have a negative effect on water quality.[4] (TRUE)	26	28	27
Elimination of forest fires would result in a change in the kinds of plants found in the Grand Canyon.[4] (TRUE)	64	55	58
Forest fires can cause air pollution equivalent to the amount of air pollution caused by automobile emissions.[4] (FALSE)	75	70	71
Cool, slow-moving forest fires are less destructive than hot, rapidly moving fires.[4] (TRUE)	43	33	37
Elimination of forest fires has increased the chances of a very large fire occurring.[3] (TRUE)	62	56	58
Average of correct answers	51	48	49

[1]Chi-square tests found no statistical differences between visitors receiving and those not receiving interpretive information.

[2]During May, three interpretive devices were used to convey the value of prescribed burning to the public. An information flyer was given to incoming Park visitors (n=29), two 1-hour campfire talks were presented (n=5), and Park naturalists occasionally discussed prescribed burning on an informal basis with Park visitors (n=13).

[3]These points are covered in the information flyer and camping talk.

[4]These points were not covered in the information flyer and camping talk.

Table 2.--Reaction of Grand Canyon National Park visitors to prescribed burning related to interpretive information about prescribed burning[1]

Class of visitors	Level of agreement[2] Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
Visitors who received interpretive information.[3] (n=47)	31.1	37.8	24.4	4.4	2.3
Visitors who did not receive interpretive information.[3] (n-76)	18.9	44.6	18.9	14.9	2.7
All respondents. (n=123)	23.5	42.0	21.0	10.9	2.6

[1]A chi-square test found no statistically significant relationship (p=0.257) between those visitors receiving and those not receiving interpretive information.

[2]Response to the following statement: "National Park Service personnel should use prescribed burning as a tool to manage Park's natural ecosystems."

[3]During May, three interpretive devices were used to convey the value of prescribed burning to the public. Of the respondents in this study, 29 had read the information flyer, 5 had attended a 1-hour campfire talk, and 13 discussed prescribed burning with a Park naturalist on an informal basis.

Table 1 indicates the percentage of correct answers for those visitors receiving and not receiving interpretive information about prescribed burning. A chi-square analysis did not indicate any significant differences between the knowledge levels of the two groups of respondents. The group receiving interpretive information responded correctly to 51 percent of the questions; the group that did not responded correctly to 60 percent. More than 50 percent of each of the groups correctly answered 7 of the 11 questions.

Not reported in table 1 is the fact that a small group (n=5) of visitors attended a campfire talk on prescribed burning. This group correctly answered 68 percent of the fire knowledge questions.

Table 2 indicates that those who received information showed more support for prescribed burning than did those who did not. Of those visitors receiving interpretive information, 31 percent strongly agreed with the use of prescribed burning, whereas only 19 percent of visitors not receiving such information strongly agreed with its use. Conversely, a lack of support was found among 7 percent of those who received information and 18 percent of those who did not.

Objective 3.--To contrast the level of support for prescribed burning between visitors aware (for example, sight, smell, sound) of burning activities and those who are not.

Table 3 indicates the level of support for prescribed burning for visitors aware and visitors not aware of prescribed burning activities. A chi-square test did not indicate any significant difference between these class of visitors. Of those visitors aware of prescribed burning, 33 percent strongly agreed with its use, whereas 22 percent of those visitors not aware strongly agreed with its use. A lack of support for prescribed burning was found among 5 percent of visitors aware of burning activities, and 16 percent of visitors not aware.

DISCUSSION

The findings of this study have precipitated three major questions in relation to visitors' knowledge of prescribed burning, their support for prescribed burning, and future research needs.

1. Why has visitor support for a prescribed fire policy increased while specific knowledge about fire has remained the same?

Since 1968, prescribed burning has increased in national parks and wilderness areas (Hendee and others 1978). Given the environmental movement of the 1960's and 1970's and the passage of such legislation as the National Environmental Protection Act and National Forest Management Act, the public has become more aware and involved in the planning and management of natural resources; prescribed burning is a part of this process. It is likely that the general public has gradually become aware of the general concept that prescribed burning can be a valuable resource management tool.

Table 3.--Reaction of Grand Canyon National Park visitors to prescribed burning related to their awareness of prescribed burning[1]

Class of visitors	Level of agreement[2]				
	Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
Visitors who were aware of prescribed burning activities.[3] (n=21)	33.3	47.6	14.3	4.8	--
Visitors who were not aware of prescribed burning activities.[3] (n-97)	21.6	40.2	22.7	12.4	3.1
All respondents. (n=118)	23.5	42.0	21.0	10.9	2.6

[1]A chi-square test found no statistically significant relationship ($p=0.501$) between those visitors aware and those not aware of prescribed burning.

[2]Response to the following statement: "National Park Service personnel should use prescribed burning as a tool to manage Park's natural ecosystems."

[3]Awareness refers to those visitors who indicated they had either seen or heard fires, had seen or smelled smoke, or had seen ashes or burned areas at the Grand Canyon.

Little effort has been made to educate the general public about the specific nature of prescribed burning and its value (Omi and Laven 1982), which may help explain why the level of knowledge about prescribed burning found in this study (49 percent correct answers) was similar to that reported by Stankey in 1976 (53 percent correct answers). To increase the general public's knowledge of prescribed burning, additional interpretive programs are necessary.

2. What role can interpretation take in a prescribed burning program? A Federal land manager must decide whether the role of an interpretation program is to increase policy support or to increase visitor knowledge of prescribed burning. If the Federal land manager desires to increase policy support, then any interpretive device that increases awareness is helpful. As indicated by table 2, the combination of three interpretive devices appears to increase visitor support for fire policy, although more definitive research is needed to document this possibility.

Awareness and support for prescribed burning may be increased by using a mass media approach (for example, newspaper, radio, information flyer). This approach is particularly desirable if a large number of people need to be contacted. Another approach that was planned at Grand Canyon National Park was a "demonstration burn" area. Park naturalist walks could be conducted, which would permit visitors to experientially learn about prescribed burning.

If the Federal land manager desires to increase knowledge of prescribed burning, a campfire talk is probably a better technique. For those visitors attending a campfire talk (n=5), the average percentage of correct answers on the fire quiz was 68 percent.

3. Given the limitations of this study, what future research needs exist? The original research design was only partially achieved because of a shortened burning program and lack of resources to obtain a larger sample. Given these limitations, we recommend that the original research design be implemented in a future study and that alternative interpretation devices and burns of varying size and duration be added as variables. This type of study could answer several questions. As fire size and duration increase, does support for fire policy decrease? Will more intensive interpretation efforts be needed? What type of interpretive device increases prescribed burning knowledge and support the most? As knowledge increases, does visitor support for prescribed burning increase? Future research efforts need to be directed to these questions.

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WILDERNESS FIRE HISTORY STUDIES IN THE NORTHERN ROCKIES

S. W. Barrett and B. M. Kilgore

Two fire history studies were initiated in Northern Rocky Mountain wilderness areas by the U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station (Northern Forest Fire Laboratory), in cooperation with Systems for Environmental Management. The first study, in northwestern Montana's Glacier National Park, was begun in 1982 to determine past fire frequencies and intensities as a prerequisite to fire management planning. The 270 fire scar samples obtained from a 60,000-acre (≅24 000 ha) study area in the North Fork of the Flathead River Basin revealed 66 fire years from the 1470's to 1960. Preliminary results indicate that large fires were relatively frequent from at least 1655 to 1926 and that many apparently were underburns in the area's predominantly lodgepole pine (*Pinus contorta*) forests.

The second study, currently in progress, was begun in 1983 in central Idaho's River of No Return Wilderness. Seventy-five fire scar samples have been collected from the first of several small study areas (5,000 to 8,000 acres [≅2 000 to 3 200 ha] each) in the area's relatively dry ponderosa pine/Douglas-fir (*Pinus ponderosa/ Pseudotsuga menziesii*) forests. These samples were obtained in a nonwilderness study area adjacent to the Wilderness. In 1984, we will sample within the Wilderness and at various locations in the Wild and Scenic River Corridor along the main Salmon River. Due to wilderness restrictions, it will be necessary to use a crosscut saw when obtaining fire scar samples within the River of No Return Wilderness.

These data will be useful to both Glacier National Park and the River of No Return Wilderness in formulating plans for the use of scheduled and unscheduled ignitions to perpetuate presettlement fire regimes in these ecosystems.

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SAGEBRUSH-GRASSLAND VEGETATIVE FUEL AND FIRE BEHAVIOR PARAMETERS FOR PRESCRIBED FIRE

Charles L. Bushey

An interagency cooperative study is being conducted to identify prescribed fire opportunities in sagebrush-grassland. The objective is to identify where fire would improve wildlife habitat and grazing allotments. A number of factors are being examined in the site review and monitoring phases; these include fuel loadings, fuel moisture, soil moisture, preburn and postburn vegetative composition and structure, weather conditions, and fire intensities.

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Five prescribed fires (using scheduled ignitions) are being conducted in cooperation with U.S. Department of the Interior, Bureau of Land Management districts in Oregon, Idaho, Nevada, and Montana. All sites are being managed as a grazing resource with wildfire considerations.

The U.S. Department of Agriculture, Forest Service, Deerlodge National Forest, has implemented a series of spring-fall prescribed fires in sagebrush- grass that is being encroached upon by Douglas-fir. These fires will be in a demonstration area established around Galena Gulch, west of Boulder, Mont. Several management scenarios utilizing prescribed burning will be examined during the next 5 years. We are currently concentrating on improving critical wildlife habitat.

HAWAII VOLCANOES: AN UNUSUAL FIRE REGIME

Chris Cameron

The Hawaiian Islands are summits of volcanoes. The land and vegetation have therefore evolved with fire. This is especially true of the Hawaii Volcanoes National Park, which is on Hawaii the largest and youngest island. Lava flows from volcanic eruptions periodically ignite vegetation near active summit and rift zone areas.

Lava flow ignitions were frequent and widespread during the 1983 series of East Rift eruptions. Several thousand acres of rain forest were underburned or destroyed by lava. Parts of a downslope subdivision were destroyed, and part of an area proposed for geothermal steam energy development was burned and covered with new lava.

Recovery of burned areas and colonization of new lava fields by native plant communities are confounded by the presence of exotic plant species, several of which are more successful pioneers than native species. The aggressive nature of exotic species neutralizes the beneficial effects of naturally ignited fires. Thus land managers are faced with a dilemma regarding decisions about lava-caused wilderness fires.

Feral goats have been eradicated in Hawaii Volcanoes National Park's lowlands and middle-elevation woodlands. Vegetation recovery includes native as well as exotic species, but the dominance of exotic grasses has produced (temporarily at least) an environment vastly more flammable than at any other time in history. It is believed that periodic prescribed fire in these areas would enhance the dominance of exotics and degrade native communities.

The Hawaii Volcanoes National Park fire management plan identified areas where rare plant communities or rare animal species habitat would be destroyed or degraded by fire. Fires would be suppressed in these areas (about 50 percent of the flammable portions of the park) and allowed to burn elsewhere.

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THE ROLE OF FIRE IN WESTERN SPRUCE BUDWORM DYNAMICS: IS WILDERNESS A FACTOR?

Clinton E. Carlson, Wyman C. Schmidt, and David G. Fellin

ABSTRACT: Effective forest fire suppression since the early 1920's has, in part, created habitat conditions quite suitable for western spruce budworm, *Choristoneura occidentalis* Freeman. In unmanaged forested lands, conifers shade tolerant for a given habitat type have flourished and developed into multistoried, dense, laddered stands providing the budworm with abundant food substrate and ideal conditions for survival of all larval stages. The dense, laddered stand conditions minimize mortality of dispersing larvae, reduce tree vigor, increase nutritional value of substrate for the budworm, and may increase the survival and fecundity of adult females. Lands that have extensive acreage of fire-protected Douglas-fir and lower subalpine fir habitat types are very hospitable for western spruce budworm. Past fire management policies in wilderness have favored continued forest succession to shade-tolerant species, concurrently favoring budworm. Current policies to allow more fire, however, should work against the budworm. Prescribed understory burning (ignition by humans) would select against the shade-tolerant laddered stand structures and would reduce stand susceptibility to budworm. Eventually the character of conifer stands in wilderness could be regulated to pre-1900 conditions to the detriment of western spruce budworm.

Western spruce budworm (WSBW) is a persistent pest of Northern Rocky Mountain Forests (Fellin and Dewey 1982); infestations of this defoliating insect have affected 3 to 4 million acres (1.2 to 1.6 million ha) annually since the early 1950's (fig. 1 and 2). From time to time lesser acreages are affected. For example, in 1981 less than 1 million acres (0.4 million ha) were visibly defoliated; however, from 1982 to 1983, populations expanded to previous levels.

Figure 1.--Western spruce budworm larvae consume primarily current year foliage of Douglas-fir, true firs, and western larch.

Figure 2.--Mature dense Douglas-fir stands on dry sites are premium substrate for the western spruce budworm, and defoliation at times is heavy.

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Western spruce budworm depends upon the forest as its substrate for survival. Changing the character of this substrate through silvicultural treatment on nonwilderness lands can create conditions unfavorable to the budworm (Schmidt and others 1983). Forested lands legally defined as wilderness, however, cannot be treated through traditional silvicultural means and in many cases are quality substrate for western spruce budworm and are infested by it. Although considered a major problem elsewhere, budworm within wilderness must be considered part of the natural ecosystem because it is a native insect and therefore may not be considered a problem. The purpose of this paper is to summarize forest characteristics favorable to budworm, relate these to current conditions in parts of several wilderness areas, and to suggest treatments that if implemented within the concepts of wilderness management would result in habitat less favorable for budworm.

Stand characteristics influencing western spruce budworm have been well documented (Carlson and others 1982; Wulf 1982). Species composition, stand density, height-class structure, vigor, maturity, intrinsic site climate, regional climate, and host continuity are important and are discussed below.

1. Species composition. Shade-tolerant species for a given habitat type are good substrate for WSBW. For example, Douglas-fir (*Pseudotsuga menziesii*) on Douglas-fir habitat types is shade tolerant relative to other conifer associates and is very susceptible to WSBW. On grand fir (*Abies grandis*) habitat types, however, Douglas-fir is relatively shade intolerant and is not preferred substrate for WSBW, whereas grand fir is highly susceptible.

2. Stand density. Dense, overcrowded stands afford more and possibly better substrate for WSBW than uncrowded stands (Cates and others 1983). More importantly, perhaps, dense stands tend to reduce dispersal loss, thereby encouraging populations to expand. Continuous crown contact intercepts dispersing larvae preventing many from spinning down to the forest floor where they would likely die. Also, the amount of substrate as food is greater in dense stands.

3. Height-class structure. Multistoried stands encourage survival of WSBW, basically for the same reasons given for stand density. In addition, the lower strata usually are composed of shade-tolerant conifers, the preferred food of WSBW (fig. 3).

4. Vigor. Vigorous, thrifty trees are less susceptible to WSBW. Stressed trees in dense stands or in stands on poor sites (hot and dry) have foliage chemically better suited to WSBW (Cates and others 1983). Specifically, resistance compounds beta-pinene and bornyl acetate are low in stressed stands.

Figure 3.--With fire excluded from wilderness, extensive areas of bud-worm susceptible climax forests have developed. Here vegetation is mostly Douglas-fir under a Douglas-fir over-story; habitat for the western spruce budworm is optimal.

5. Stand maturity. Generally, older mature stands are more susceptible to WSBW (Cates and others 1983; Wulf 1982). Young stands less than 20 years old tend to be only slightly susceptible.

6. Intrinsic site climate. WSBW appears to succeed best in warm, dry locations (Carlson and Theroux 1982; Stoszek and Mika 1983). Thus, south-facing aspects on moderately steep slopes at lower elevations generally are a good environment for the insect, whereas north-facing slopes at higher elevations are relatively poor.

7. Regional climate. Regional climatic patterns characterized by wet, humid conditions tend to discourage WSBW outbreaks (Kemp 1983). For example, forests in northwestern Montana, northern Idaho, and western Washington are not very susceptible to WSBW, regardless of stand condition; however, north-central Washington, west-central and central Montana, and parts of north-central Idaho are quite dry, and forests there tend to support recurring outbreaks of budworm.

8. Continuity of host type. Stands adjacent to or surrounded by extensive areas (>1,000 acres [≅400 ha]) of susceptible host type have an inherently higher probability of infestation than do stands surrounded by small amounts of host type (Mott 1963).

Knowledge of the factors influencing stand susceptibility to WSBW allows us to infer why the insect has become such a widespread problem. We strongly suspect that reducing fire in wild stands, along with "economic selection" logging practices, has created stand conditions favorable for WSBW. Absence of fire favors forest succession toward climax. In this successional process, shade-tolerant conifers survive and develop into multistoried, dense stands of relatively low vigor (Gruell and others 1982). Western Montana has extensive areas of lower subalpine fir habitat types that are dominated by seral species (western larch [*Larix occidentalis*] and Douglas-fir) but have dense understories and intermediate canopies of subalpine fir (*Abies lasiocarpa*). These forests are highly susceptible to budworm.

Exclusion of fire from wilderness has encouraged development of stands highly susceptible to WSBW. For example, forests over much of the East Fork of the Bitterroot River, which is in the Anaconda-Pintlar Wilderness, are multistoried and dense. Subalpine fir, highly susceptible to budworm, constitutes most of the biomass. This pattern is evident in other western wilderness areas including the Selway Bitterroot, Bob Marshall, Scapegoat, Spanish Peaks, and Welcome Creek, where budworm is common.

In the absence of fire, WSBW becomes a weak force in maintaining seral conifer communities; it is a weak substitute for fire. Extensive heavy budworm feeding damages conifer hosts, the shade-tolerant species, and causes significant mortality in the younger, smaller age classes (Bousfield and Williams 1977). Even though feeding injury is natural, heavily defoliated trees may not add much to wilderness quality as perceived by users.

It has been suggested and supported by inference that fire may be an important regulating force in WSBW dynamics. Wilderness indeed is an important factor because in the past fire was quickly suppressed in habitat types most favorable to budworm, and timber harvesting has not been practiced, allowing highly susceptible stand conditions to develop. These budworm-susceptible stands in wilderness may be a hazard to contiguous lands because they produce larvae and adult budworms that may disperse to forests outside the wilderness boundary (Mott 1963; Campbell 1984). However, research by Mott (1963) was done in the Eastern United States on a different but closely related budworm species and may not represent western conditions. Campbell's (1984) work is preliminary but does suggest that female budworm moths may migrate between stands; just how far they go is speculative.

Silviculture cannot be used to reduce stand susceptibility in wilderness--timber harvesting simply is not allowed. On nonwilderness lands, even-aged silvicultural practices can be used effectively to reduce stand susceptibility to WSBW (Carlson and others 1982; Schmidt and others 1983). Some sort of remedy in wilderness appears to be in order if one considers that WSBW has intensified in wilderness because of our past fire control policies. In these circumstances increased budworm intensity is an unnatural, unplanned result of human activities. Prescribed burning (deliberate or natural ignition) of understory may be an acceptable option to restore forests to pre-1900 status and may be worth consideration. Light, low-intensity ground fires can be effective in reducing the density of shade-tolerant understory conifers (Arno 1983) and should encourage development of seral communities relatively nonsusceptible to WSBW (fig. 4).

Prescribed fire in wilderness is being used today as a wilderness management tool, but generally the ignition must be natural (lightning). Prescribed ignition by humans represents a philosophical change in wilderness fire policy. If implemented, this policy should reduce WSBW habitat; the effects should be monitored and documented. For example, of about 26 naturally ignited fires in the Selway-Bitterroot Forest in 1983, only 2 were suppressed (Mutch 1983). Data concerning stand characteristics before and after the fires would show whether WSBW habitat had been reduced in those stands.

Prescribed fire with ignition by humans could be used to reduce budworm habitat and may augment other wilderness values such as wildlife. This may, however, be construed by many people as unnatural intervention. Perhaps a program that includes both natural and human ignitions and that approximates pre-1900 fire frequencies would be appropriate and may eventually lead to an extensive mosaic of stands, thus making wilderness forests less of a refuge for western spruce budworm.

Figure 4.--Underburning in wilderness could be used to destroy shade-tolerant understory conifers that are good habitat for western spruce budworm, maintain stands at a seral level, and reduce general stand susceptibility to the insect.

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AUSTRALIA'S 1983 "ASH WEDNESDAY" FIRES

N. Phil Cheney and Charles George

In Southeastern Australia, drought conditions persisted for much of 1982 and continued on into 1983. By January a severe rainfall deficiency had existed over most of southeastern Australia for 10 months. Much of South Australia (SA) and the forest areas of Victoria had their lowest rainfall on record for the 10-month period ending January 31, 1983 (Zillman 1983). In New South Wales (NSW) and northern Victoria pastures were completely eaten out, practically eliminating the danger of grass fires in those areas, but forest fuels were extremely dry from the south coast of NSW through to Adelaide, SA. There were few areas in South East (SE) Australia carrying reasonable pasture. One of these was in the SE of South Australia, which normally has quite extensive areas of moist swamps in most summers.

The driest forest zone was in eastern Victoria. Three major fires of 30,000 acres (12 000 ha), 67,000 acres (27 000 ha), and 50,700 acres (20 500 ha) burnt during November. On January 8, 30,000 acres (12 000 ha) of forest were burnt in central Victoria and two firefighters were killed. Up to this stage most fires had been confined to sparsely populated forest areas. Pastures in eastern Victoria were sparse and eaten out and fire suppression in the grasslands presented few problems.

On February 1, more fires broke out in the forests of Victoria under strong northerly winds in association with a dry cold front. The Cann River fire in east Gippsland burnt more than 247,000 acres (100 000 ha) over 12 days, crossed into NSW and burnt 13,600 acres (5 500 ha) of *P. radiata* plantation. This was a record loss for a plantation fire in Australia with damage estimated at $12 million --a record that was to be short lived. Another fire in Mt. Macedon, a fashionable residental area within commuting distance of Melbourne, burnt 14,800 acres (6 000 ha) and 24 homes.

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On February 15, an anticyclone over New Zealand extended a ridge towards central Australia, and in the Southern Ocean a cold front was advancing northeastward. The pressure gradient over eastern Australia was fairly weak and surface winds were light. This is a familiar pattern in summer and usually recurs every 7-8 days. The pressure gradient usually becomes steeper as the front approaches, bringing stronger dry northerly winds to southern Australia ahead of a cool change with south to southwesterly winds.

A deep reservoir of hot dry air existed over central Australia. This was drawn south by large pressure falls in the Great Australian Bight and a new front formed ahead of the front in the Southern Ocean. During the morning of February 16, Ash Wednesday, this new front intensified and gale-force northerly winds carrying dust from the parched interior swept over South Australia and western Victoria, dramatically reducing visibility. The front moved across South Australia during the afternoon and winds appeared to be intensified by the approaching cold front in the Southern Ocean. Mean windspeeds of 25 to 30 mi/h (40 to 50 km/h) were recorded in open locations before the change. After the change, mean winds were SW around 44 mi/h (70 km/h) with gusts over 68 mi/h (110 km/h), and these persisted for more than 2 hours.

In both States (SA and Vic.) fires broke out and burnt rapidly southward under the influence of the gale-force northerly winds. Suppression of the flanks was impossible; and when the wind changed to the SW, the fires broke away along the whole of the eastern flanks. In the most extreme case the fire had travelled 37 mi (60 km) in a southerly direction before the change.

In the Adelaide Hills, 7 fires burnt 96,100 acres (38 900 ha). Again sparse pasture limited the rates of spread in grasslands, and the major spread and damage occurred in timber and scrub areas near Adelaide. Fourteen people were killed and 260 houses were destroyed or seriously damaged.

In the SE of the State pastures were light but continuous, and rates of spread 11 to 12 mi/h (18 to 20 km/h) were recorded for several hours. Here 8 fires burnt over 300,000 acres (120 000 ha) including 47,700 acres (18 500 ha) of pine plantations. Rates of spread in the plantation were up to 6 mi/h (10 km/h). Fourteen people were killed and 123 homes were destroyed.

In Victoria, 8 major fires burnt 450,000 acres (183 000 ha) on the 16th and wiped out several towns and seaside resorts. Forty-seven people perished and 2,186 homes were destroyed. Estimates are that the cost of the fires may exceed $400 million.

Over the 1982/83 fire season, the Forests Commission of Victoria lost 1,280,000 acres (518 000 ha) of native forest but only 5,800 acres (2 360 ha) of pine plantations (Duncan 1983).

The fire weather conditions on Ash Wednesday (February 16, 1983) were similar to those which occurred on January 13, 1939, the worst fire season on record. Windspeeds recorded at Melbourne on both days underestimate the winds in open and forest areas. The maximum forest fire danger on both days exceeded an index value of 100 in many areas.

It is possible that these conditions may have a return period of 50 years although conditions of extreme fire danger (FFDI >50) occur much more frequently. Under these extreme conditions known suppression techniques and firebreaks will fail. Fuel reduction programs can limit the spread and intensity of wildfires, but to be effective they must be applied to a significant proportion of the forest estate each year.

As the history of native flora and fauna becomes better understood, it will be possible to prescribe fire regimes that will achieve the joint aims of conserving natural values and protecting commercial timber resources from high intensity wildfires.

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FIRE ECOLOGY OF FOREST HABITAT TYPES: AN AID FOR FIRE MANAGEMENT PLANNING

Marti Crane

Schematic models for managers interested in predicting forest succession are being prepared for various regions in the Rocky Mountains. The models are developed for "Fire Groups," which are aggregations of habitat types with similar responses to fire. Criteria for grouping include the predicted climax species for the habitat type, probable seral species, the fire regimes, and general physical properties of the habitat types. Pertinent literature is summarized by Fire Group for each region. The models predict successional stages in the absence of fire and probable effect of fire occurrence at each successional stage. Fire effects are predicted for low-, moderate-, and high-severity fires in all models. The models show only the effects of fire and fire exclusion. Other disturbances are excluded to keep the models relatively simple and to emphasize fire's role.

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THE ROLE OF FIRE IN ASPEN ECOLOGY

Norbert V. DeByle

ABSTRACT: The tree with the widest range in North America, quaking aspen (*Populus tremuloides*), occurs on more than 7 million acres (2.86 million ha) in the nine interior Western States (Colorado, Utah, New Mexico, Wyoming, Arizona, Idaho, Montana, South Dakota, and Nevada). About 65 percent of the land is in public ownership; this includes many acres of wilderness at mid to high elevations.

Aspen is seral on most sites. It colonizes and dominates burns, clearcuts, and other disturbed locations. Maximum aspen biomass is attained between 50 and 100 years after stand establishment. Some time later, between 200 and 400 years, the aspen is often replaced by conifers on most cool-wet sites and with shrubs and grass on warm-dry sites. Aspen on many sites in the West, however, is quite stable and may remain for centuries without appreciable successional change.

Abrupt destruction of an aspen or mixed aspen-conifer forest, usually through fire or clear-cutting, sets back plant succession and results in a stand of aspen root suckers. Hundreds of suckers may come from the roots of a single parent tree; thus, a scattering of aspen trees can be transformed by fire into a complete stand of aspen suckers. Even though aspen seed is produced in abundance, successful regeneration from seed is rare in the montane West.

Aspen possesses several characteristics that make it a likely dominant tree on any burned area that contained a detectable aspen component before burning. These are:

1. Aspen trees are readily killed with fire; they have thin, smooth bark that has little heat resistance.

2. The root systems of these killed trees send up a profusion of suckers (sprouts) for a couple of years. Thus, 150 mature aspen per acre in the preburn forest may easily produce 30,000 sprouts per acre within 2 years after a fire.

3. Aspen root suckers grow rapidly by extracting water, nutrients, and foods from an extant root system and may outcompete most other woody vegetation.

4. Following a burn, a new, even-aged, closed-canopy, aspen forest can develop within a decade. This pioneer species grows best in even-aged stands in full sunlight.

5. In contrast to many conifers, dense stands of aspen suckers are self-thinning. Without intervention, a mature forest of healthy trees will develop from the densest of sucker stands.

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PRESCRIBED FIRE MONITORING IN SEQUOIA AND KINGS CANYON NATIONAL PARKS

Diane M. Ewell and H. Thomas Nichols

ABSTRACT: The prescribed fire monitoring program in Sequoia and Kings Canyon National Parks is designed to document and predict fire behavior and fire effects. Data are collected before the burn and for 10 years after on vegetation (trees and shrubs), pests and diseases, and fuel loadings. Fire effects are related to observed fire behavior. This paper describes the purpose of the monitoring program, monitoring methods, and data analysis and evaluation.

INTRODUCTION

The goal of the fire management plan for Sequoia and Kings Canyon National Parks (Bancroft and Partin 1979) is to maintain or restore the natural fire regime as one of the processes within these parks. The natural fire management zone in Sequoia and Kings Canyon National Parks, in which almost all lightning fires are allowed to burn, includes 727,000 acres (≅294,000 ha), or close to 84 percent of the total area of these parks. The other 16 percent is also generally managed as a natural area but requires prescribed burning[1] to remove hazardous fuels before natural fire can be allowed to burn.

These two phases of the fire management program are closely linked. The techniques, prescriptions, and objectives of the prescribed burning program are guided by the behavior and effects of natural fire in similar vegetation types that have been relatively unaffected by fire suppression because of their more remote location in these parks.

Fire monitoring therefore has two aspects. First, the short-term guide for these parks (Nichols 1983) focuses on predicting and documenting fire behavior and immediate postfire effects such as scorch height and fuel reduction. Because prescribed natural fires and prescribed burns may involve thousands of acres and persist for several weeks, accurate prediction of fire behavior is critical if public safety and various legal constraints are to be uncompromised.

The second aspect is more subtle. The goal of the fire management program is to restore or maintain the natural fire regime. The function of long-term monitoring (Ewell 1983) is to document that this is being done within a specific vegetation type by prescribed burns, subsequent natural fires in prescribed burned areas, and natural fires in remote areas.

Previous studies in these parks generally have reported on fire's effects from prescribed burns. Two studies involved natural fires in the Sugarloaf Valley in Kings Canyon (Greenlee and others 1979; DeBenedetti and Parsons 1979), and three have dealt with fire history (Kilgore and Taylor 1979; Pitcher 1980; Warner 1980). Nevertheless, monitoring emphasis generally has been on the short-term effects of fire, although the natural fire study by Greenlee included long-term herb recovery and tree regeneration. Studies by Parsons and DeBenedetti (1979), Bonnicksen and Stone (1981), and Vankat and Major (1978) addressed successional changes resulting from fire suppression.

Use of the long-term monitoring guide is the first attempt to record preburn ecosystem variables and fire characteristics and to follow fire-induced changes over several years in these parks. The forest ecosystem variables that are measured as part of the long-term fire monitoring program include those recommended by the Prescribed Fire Monitoring and Evaluation Guide (van Wagtendonk and others 1982). These include intensive tree measurements, shrub and seedling cover by species, fuel loading appraisal by individual size classes, and general site characteristics. The following sections review the monitoring methods, data analysis, and evaluation.

MONITORING METHODS

Permanent 0.25-acre (0.1-ha) plots are stratified by tree overstory composition as described by Rundel and others (1977). The mixed conifer type is further divided into sequoia mixed-conifer, white fir-mixed conifer, and mixed conifer

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[1]Editors' note: please refer to Foreword for comments on prescribed fire terminology.

(Parsons and DeBenedetti 1979). Before the fire at least four plots are set up on the area to be burned, and one control plot is set up outside the burn area. Within the boundaries of each plot, vegetation, fuel loadings, slope, and soil type are relatively uniform. The plots are as similar as possible to the control plot's vegetation and physical characteristics. The control plot is in the same drainage or as close as possible. The plots are 164 by 66 ft (50 by 20 m) and divided into four quarters as shown in figure 1. The 164-ft (50-m) midline is placed parallel to the contour of the slope. General plot information such as midline compass bearing, Universal Transverse Mercator (UTM) coordinates, general location description, soil texture, aspect, and slope are recorded. Photographs are taken at two fixed points. The time of season and the previous winter's precipitation as compared to the average year are noted, as well as the stage of the flowering plants, so that the plot may be resampled at approximately the same phenological period.

For each tree within the plot, diameter at breast height (4.5 ft [1.4 m]), crown position, tree damage, live crown ratio, and presence of forest pests or diseases are determined. Postfire tree measurements are as follows: the scorch height and live crown scorched on each tree; minimum, maximum, and average char height on the bole; and estimated mortality as described by Dieterich (1979).

Every tree is numbered, tagged, and mapped for each quarter section of the plot. Other tree species not sampled inside the plot, but found in the same ecotype surrounding the plot, are noted. Overstory canopy cover is estimated for all species and for each species.

Trees less than breast height (small trees) are sampled separately. The small trees in an area of 328 ft^2 (100 m^2) are tallied by species, number, height class, and cover. Small tree species not sampled, but found inside the plot, are noted.

Random direction 49-ft (15-m) transects are placed at 32.8, 65.6, 98.4, and 131.2 ft (10, 20, 30, and 40 m) along the midline using Brown's planar intercept method (Brown 1974) to estimate fuel loadings. Litter depth (needles and woody material less than one-fourth inch [0.64 cm]) and litter and duff depth (all litter and decomposed material except woody material) are measured at five points along the transect line. Each transect line is extended across the midline for an additional 16.4 ft (5 m) for a 65.6-ft (20-m) shrub transect. The distance intersected along the line by shrubs is recorded for each shrub species. Again, shrub species not sampled but found within the plot are noted.

As a plot burns, rate of spread and flame length at 24.6 ft (7.5 m) on the fuel transects are observed and recorded. Windspeed and direction, relative humidity, and temperature are the weather variables measured. The fire type (head or backing) and wind and fire slope direction (up, down, or cross slope) are noted. Litter, duff, and 10-hour fuel moisture are determined by sampling and fuel moisture scale. Photographs are taken from the two photo points and of the four fire behavior measurement points.

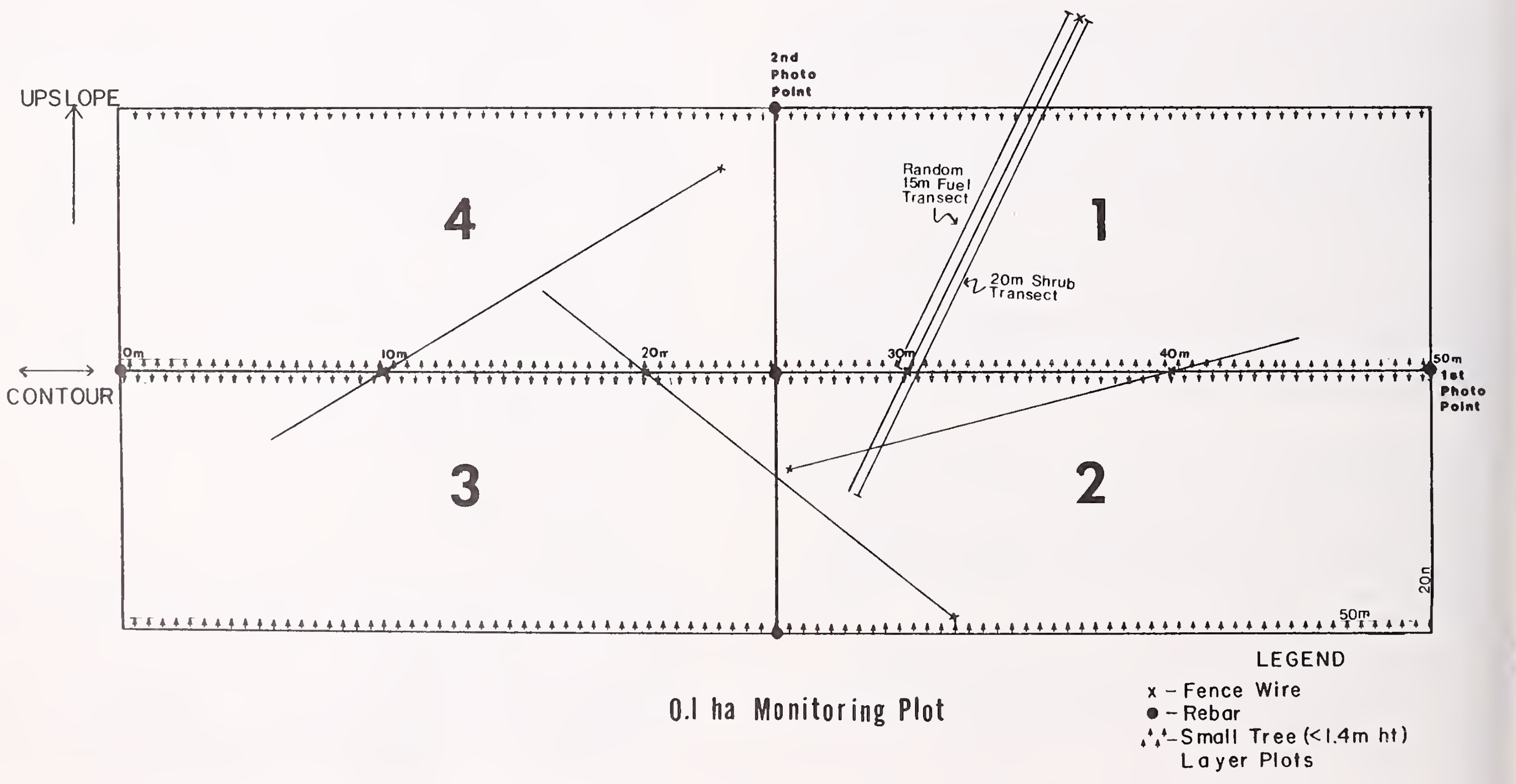

Figure 1.--Schematic diagram of the long-term fire monitoring plot for Sequoia and Kings Canyon National Parks.

Resampling is to continue for 10 years with intervals as follows: before and after fire and 1, 3, 5, and 10 years after fire with the exception of small trees, which are also sampled 2 years after fire. Some variables are not measured at each sampling interval because of the time required to detect any changes. The 10-year-monitoring period may be extended if a longer period is necessary to obtain sufficient data and associated trends.

DATA ANALYSIS

Significant results are identified within individual plots, between control and burn plots, and between plots of the same vegetation type. Forest successional changes are analyzed by overstory and understory changes by species density, size class (by diameter or height), distribution in space (dispersed, aggregated, clumped, or random), dominance, and cover. Reduction and accumulation of fuels are also analyzed. Fire-related and nonfire-related results are to be determined by comparing burn plots with control plots.

All results are correlated with one or more of the following observed or predicted fire behavior variables: flame length, rate of spread (spread component), fireline intensity, burning index, ignition component, reaction intensity, energy release component, and heat per unit area. The predicted fire behavior variables are calculated from the Fire Behavior and Fire Danger programs using the observed fire behavior, weather, and fuel moisture data taken on the monitoring plots (Deeming and others 1977; Rothermel 1983). The observed plot data are also used to develop park-specific fuel models with the new BEHAVE system (Andrews 1983).

EVALUATION

The data collected are applied to preestablished, quantifiable objectives. Restoring or maintaining natural tree composition and size class distribution, improving sequoia regeneration, and reducing fuel loadings are examples of objectives research has helped to quantify. For example, research into fire scars has provided information on the natural fire regime in terms of fire size, intensity, behavior, and season of burning. Given this information, monitoring shows whether specified management strategies are restoring or maintaining this fire regime.

As prescribed fire objectives become more specific, the adequacy of the monitoring program may be more readily determined and the program can be improved as necessary. Unless a thorough monitoring program is developed, managers will not be able to document that prescribed fire program's objectives are being achieved.

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SOME CLIMATIC CHARACTERISTICS OF GLACIER NATIONAL PARK

Arnold I. Finklin

ABSTRACT: This study focuses on climatic features of Glacier National Park that may influence decisions made by fire managers and others concerned with maintaining wildland ecosystems and resources. I studied the fire season (particularly July and August, having the most available data), but also examined the annual climatic regime. Various maps and graphs portray the spatial patterns and seasonal (monthly and 10-day) courses of average temperature, relative humidity, windspeed, and precipitation; also the frequency distributions of particular values. Station averages (many not previously presented) are based on or adjusted to the 30-year normal period, 1951-80.

Contrary to some statements in the literature, the eastern edge of Glacier Park receives as much precipitation as the western edge; for example, East Glacier and West Glacier both average about 30 inches (760 mm) annually--with similar seasonal distribution--and St. Mary averages several inches more than Polebridge. Stronger winds observed on the eastern side, however, appear to have a considerable drying effect. Seasonal patterns of average temperature and relative humidity are also similar on the east and west sides. Though large contrasts can occur across the Continental Divide on individual days, there is generally a high interstation correlation of afternoon temperature values, as shown by correlation coefficients.

Fluctuations or trends of seasonal and annual average temperature and precipitation during this century are examined by use of 11-year and 5-year (weighted) running means. An increase in summer (July-August) precipitation that began in the 1970's is notable. Conversely, early autumn (September-October) has been exceptionally dry in recent years. At the fire-weather stations, July-August afternoon relative humidity observed during 1974-82 averaged around 10 percent higher than for the 1951-70 period. This appears to reflect a more moist, unrepresentative summertime regime, but up to one-half of the difference may result from a change in observation time initiated in 1974 (from 4 p.m. to 1 p.m., m.s.t). Temperature and precipitation conditions during the preceding months are not a strong predictor of weather during the summer season. At best, at West Glacier, a late spring (May and June combined) with defined warmer-than-normal average afternoon (maximum) temperatures was followed by a correspondingly warm July-August in 60 percent of the limited sample years and a cool July-August in 20 percent. The test result was not statistically significant. Practically no correlation was found between July and August average temperatures or between the precipitation amounts.

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NATURAL REVEGETATION FOLLOWING THE 1950 PORCUPINE RIVER FIRE IN NORTHEAST ALASKA: 1951-81

Joan Foote

Fire is an integral part of the forest ecology of the taiga of interior Alaska. For years people have observed the immediate and general impacts of fire on vegetation. Few have documented their observations of these fires, and even fewer have observed a given burn through time; however, the revegetation of one wildfire, the 1950 Porcupine River Fire, has been studied intermittently since 1951.

This fire resulted in a 520,000-square mile (≅135 million ha) burn that extends along the Porcupine River Valley from near the Alaskan-Canadian border southwestward to the Coleen River Valley. The closest towns are Old Crow to the east and Fort Yukon to the southwest. This burn is remote; accessible only by boat, float plane, or helicopter.

Permanent vegetation transects were established in 1951 and 1954 by the Cooperative Wildlife Research Unit at the University of Alaska. Additional permanent vegetation plots were established in 1971 by the Institute of Northern Forestry. Species composition and cover were studied along the transects in 1951, 1954, 1957, 1961, and 1973; the plots were studied in 1973 and 1981. This is the oldest long-term study of this type in interior Alaska.

This poster, using photographs, graphs, and charts, illustrates the changes and trends that have occurred to natural vegetation over a 30-year period. Before the fire, white spruce and balsam popular were found on the well-drained flood plains; white spruce and an occasional paper birch, on the low ridges and better-drained areas above the bluffs; and black spruce was found elsewhere. After the fire, vegetation developed from root and stem sprouts, seed from scorched black spruce cones, light airborne seed and spores, and heavier airborne seed. Moss and herb species dominated the area 6 years after the fire, and willows and hardwood saplings 23 years after the fire. Thirty years after the fire, hardwood trees overtop the shrubs, the spruce are 6.6 to 13.1 ft (2 to 4 m) tall, and a few have cones. These findings agree with those of other shorter-term studies in other areas in the Alaskan taiga.

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METEOROLOGICAL TOOLS FOR WILDERNESS FIRE MANAGEMENT

Douglas G. Fox, James O. Blankenship, and David L. Dietrich

ABSTRACT: This paper describes available techniques that provide fire managers with meteorological information. Conventional weather stations and remote automated weather stations provide a background data set that can supplement on-site balloon-borne data collection. All the data can be used by terrain-oriented wind and dispersion modeling systems to provide wind maps and pollution patterns for planning and operational purposes.

INTRODUCTION

Meteorological information is critical in fire planning and management. Fires in wilderness require more information than their counterparts in nonwilderness. Providing the meteorological intelligence needed to adequately plan wilderness fire programs and to appropriately manage effects from fires (such as smoke) is difficult, because the data on which to base any forecast or even an analysis of current conditions is sparse, if available at all. Developing meteorological intelligence, therefore, is an exercise in creative data gathering, coupled with appropriate use of analysis and simulation models.

The progress in atmospheric sciences was well stated in the recent U.S. Department of Agriculture, Forest Service, Atmospheric Sciences Workshop Proceedings (USDA Forest Service 1982). To quote, "Advancement of knowledge . . . has invariably resulted from the availability of new observational information, or new information processing methods . . . ." This paper describes techniques that have recently been developed to aid in the collection of new observational information. Equally important, it describes new information processing models that are able to use the observations in a meaningful manner to provide meteorological intelligence in a concise and useful format.

Meteorological data on wilderness are lacking because wildernesses are usually in remote, high-elevation areas where routine meteorological observations are minimal. In addition, the procedures meteorologists use to forecast the weather, basically numerical simulation models run with measured initial conditions, are notoriously inadequate in regions of complex topography. Because of its special needs, the fire community has developed its own network of fire weather observations (Furman and Brink 1975). Wilderness, however, is even more remote than the areas encompassed by this network. Thus, the first challenge to providing meteorological intelligence for wilderness operations is to develop some data resources for wilderness.

Once data are available, it is necessary to determine what the data mean. In mountain terrain the location of a meteorological measurement is critical to its meaningfulness. Just how much of the area around the measurement experiences similar meteorological conditions and how long a time the same conditions persist are not easily established, but this information is essential when one wants to use the data. The question of how representative data are has been addressed by a recent American Meteorological Society Workshop (Nappo and others 1982). Although analytical techniques are available for flat terrain (for example, Furman 1984), such procedures do not work in the mountains. We know that the representativeness of a measurement is a function of its location. The problem is to locate measurements that represent as much as possible of the critical meteorological regime of concern to the manager. Our experience, using techniques described in more detail below, has been that station siting can be successfully accomplished as an interactive process involving models that simulate a distribution of the meteorology for the area, individuals knowledgeable about the local conditions, and individuals knowledgeable about the purpose (objective) of the measurement. Although it would be nice to think of this process objectively, it remains a subjective process in which the analytical tools are an important aid but do not provide final answers.

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Once data are collected in a representative fashion, what can they be used for? To answer this one must consider the objectives of particular applications. Only when the manager has a clear picture of the planned application and of the various decision points in the application will the meteorological information be useful. The meteorological information should facilitate decisionmaking. Further, for meteorological information to be useful, the intelligence must be an improvement over what it replaces. Often the manager has a rough concept of the local climatology. In addition, individuals are usually available who have had quite a bit of site-specific experience with the weather conditions of an area. Not only can a model improve on knowledge of the average condition, but it can be useful for the deviation from the average--the nonnormal condition. Also, when "local expertise" is not available, the model and its supporting data can provide a portion of this knowledge.

A final point should be mentioned about the stochastic nature of the atmosphere. Uncertainty is always a factor when winds and other meteorological variables are being predicted. Each variable has random characteristics that make two choices possible when these variables are modeled. One can simulate the randomness, leaving a complex picture of variability, or one can do some averaging and simulate a mean condition. In general, the equations solved represent an ensemble average --namely, an average over a number of repeats of the same conditions. Because the same conditions rarely occur in the atmosphere more than once, one should not expect precise numerical comparisons between a model prediction and what actually happens. Indeed, comparisons between meteorologically based observations and meso- and smaller-scale model predictions are generally poor. This difference gives rise to an inherent uncertainty in predicting meteorological variables (Fox 1984). Indeed the best one can hope to do is provide some general indications and to attempt to bracket this uncertainty by providing high and low estimates of the likely range of the variable. This inherent uncertainty is an important concept that should be factored into all meteorologically influenced decisionmaking.

The remainder of this paper provides an overview of some of the modern technology available to provide meteorological intelligence for wilderness fire needs. The applications section describes briefly some of the data-gathering tools that have recently become available. The next section describes a model system we have developed over the past 5 years to provide information on the distribution of wind and air pollutants over highly complex topography. The last section indicates the likely utility of these tools to the wilderness fire problem.

RECENT ADVANCES IN MEASUREMENTS

Meteorological measurement has improved as a result of computers and satellites. The computers have allowed rapid processing of rather complex signals returned from remotely operating sensors. Satellites have taken increased advantage of digital data processing capabilities by providing a communications link between the decisionmaker and remote locations. A dramatic increase in our ability to measure the meteorological conditions of remote locations has occurred with the introduction of routine application of remote automated weather stations (RAWS). RAWS (Warren and Vance 1979) include solar-powered microprocessors that regularly interrogate a set of conventional meteorological sensors and then transmit that data through the Geostationary Orbiting Environmental Satellite (GOES) to various earth station locations (Furman 1982). RAWS are reasonably portable and comparatively inexpensive, making them ideal instruments for short periods of data gathering. Short-term local data can be quite useful if they are factored into the existing fire weather data library or some other long-term archive. Since RAWS are not elaborate, they can usually be deployed within or near wilderness so long as the purpose in using their data is a benefit to the wilderness.

An indication of the type of data gathered and what can be done with it is shown in figure 1. Figure 1 illustrates an airflow pattern measured by RAWS in the vicinity of San Antonio Mountain (McCutchan and others 1982) under three distinctly different types of conditions. This figure indicates the type of wind data one might obtain with enough

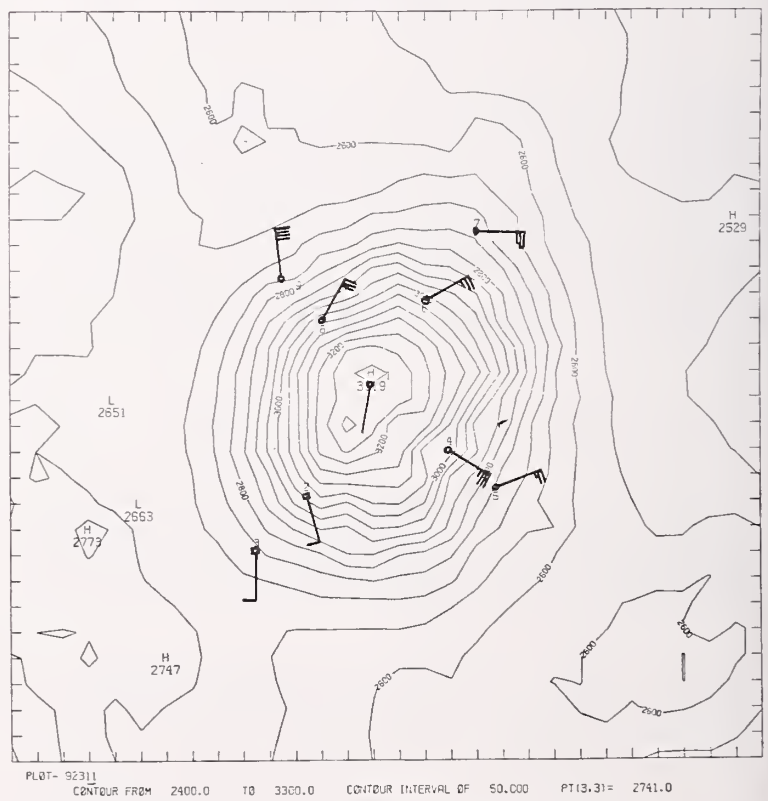

Figure 1a.--Airflow pattern measured by RAWS in the vicinity of San Antonio Mountain on September 17, 1981. Upslope draft--very light low aloft. Full barb is 2 mi/h (1 m/s), half barb is 1 mi/h (0.5 m/s), and a pennant is 11 mi/h (5 m/s).

Figure 1b.--Drainage flow--very light flow aloft.

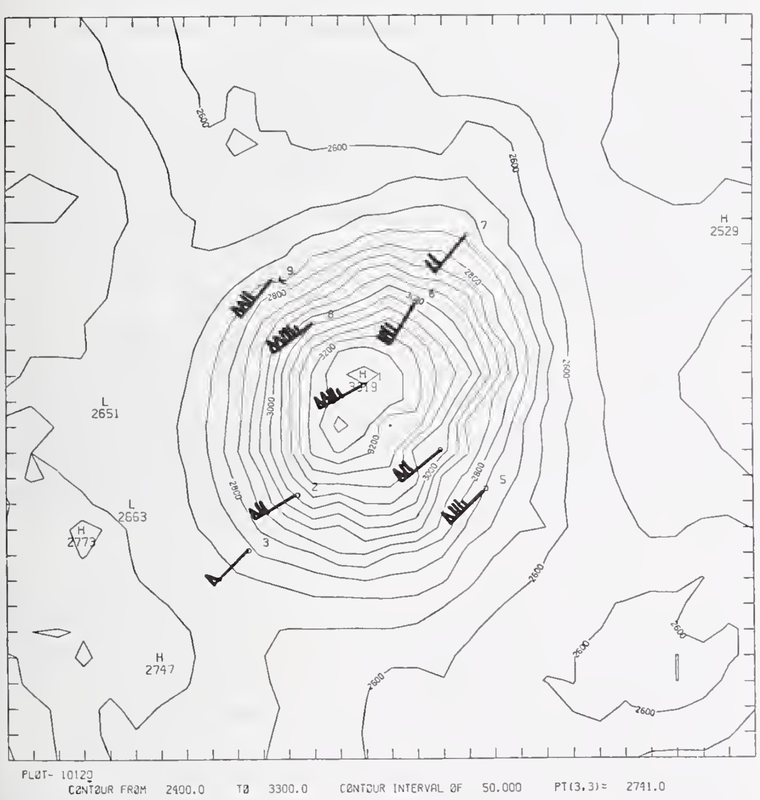

Figure 1c.--Strong flow aloft.

RAWS located in a small area. Obviously, using one wind to represent the pattern is acceptable only when the topographic influence is insignificant. When the windspeed is above about 22 mi/h (10 m/s) at the top of the hill, the hill has little or no influence. Even in this case considerable windspeed (not direction) variation is exhibited from one side (upwind) to the other (downwind) of the mountain. It is obvious that more complex topography would provide more complex patterns. Although RAWS provide a ground level of information, they must be supplemented with a different type of data whenever the application requires information about the vertical structure of the atmosphere. Figure 2 shows the results of tracking two different types of free-flying balloons. Figure 2a shows the velocity field as identified by pilot balloons (pibals) released at 0800, 0940, and 1100 on September 17, 1981 in the vicinity of San Antonio Mountain. Pibals are small (about 3 feet [1 m] in diameter), helium-filled balloons with sufficient positive buoyancy to rise through the atmosphere. Figure 2b

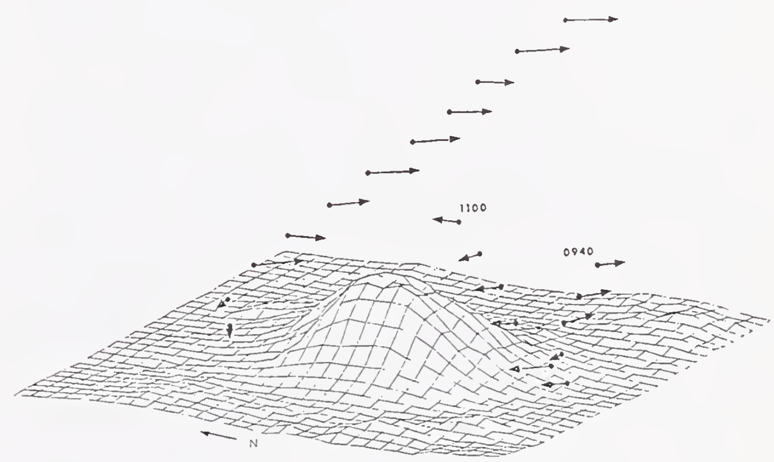

Figure 2a.--Results of tracking two different types of free-flying balloons on September 17, 1981, over San Antonio Mountain. Computer-drawn wind vectors calculated from pibal flights; length scale can be judged from the mountain height (appox. 2,625 ft [800 m] and width approx. 2 mi [3 km]). Balloons launch times are indicated in Mountain Standard Time.

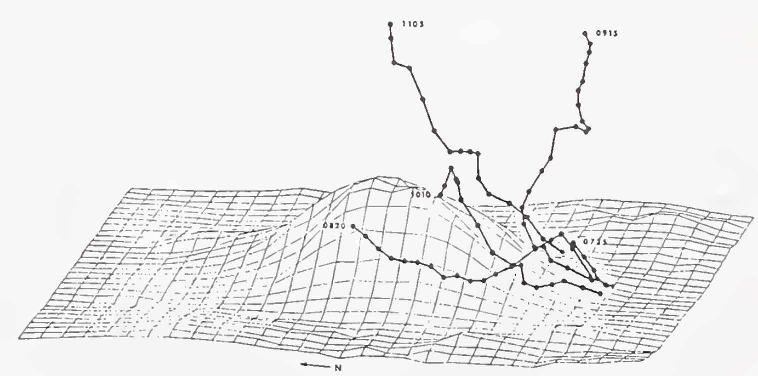

Figure 2b.--Air trajectories calculated from constant-volume balloon data; the dots represent air positions at 2-minute intervals.

shows the trajectory of constant-volume balloons released at roughly the same time and location. Constant-volume balloons are designed to fly at a preselected level above the ground. Deviation from that level (as experienced by the 0915 and 1105 balloons) suggests the presence of significant vertical motions.

The velocities in figure 2a and the trajectories in figure 2b are determined by tracking the balloons by theodolite and recording each balloon's position at various times. Recent technological developments have improved the accuracy and simplicity of tracking balloons. Some of the improvement results from the use of small, light instrument packages carried by the balloon. The instrument package contains sensors that measure air temperature (wet and dry bulb) and pressure (height of the balloon). These data are telemetered to a microcomputer, where they are recorded and displayed in very near real time. The tracking for the constant-volume balloon requires two theodolites along with the pressure data in order to define its three-dimensional motion. The pibal can be tracked with a single theodolite because its horizontal motions are rather small compared with its significant buoyancy--induced rise rate. Tracking can be simplified greatly by using automated theodolites. The current technology allows visual tracking, but with the theodolite wired to a microprocessor, position can be determined without any dials being read. The results can be processed and displayed in near real time so that the individual on site has instant access to the wind patterns.

Similar technology is available to measure, at a single point, a profile of meteorological measurements by equipping a large balloon with an instrument package and a tether line and then running the balloon up and down to measure the windspeed and direction, temperatures (wet and dry bulb), and balloon height.

A few of the advantages these balloon-borne measurements provide include:

1. Portability.--All the equipment necessary to conduct a wind survey using balloons can easily be packed into a remote area. The electronics are contained in two briefcase-sized cases, and the only other major item needed is helium to fill the balloons.

2. Expense.--The initial system cost is about $20,000, much of which is the theodolite cost. Each balloon-borne measurement flight costs about $100 if the instrument is not retrieved.

3. Data quality and utility.--Balloon data are lagrangian (for example, they are measurements within the flow system). These data are preferred to answer such questions as where will the smoke go.

4. Operator simplicity and ruggedness.--Although it requires some significant training, the operation of a balloon-based observation is quite easy. Instrumentation has proven quite reliable over the past 3 years of operation.

In conclusion, measurement technology has advanced quite rapidly in the past few years. The current technology allows the manager much improved capability to make meteorological measurements in remote locations.

MODELING ADVANCES

Many models have been developed over the past few years to provide information for fire managers. This paper, concerned with wilderness fire, addresses the provision of meteorological intelligence, especially modeling wind fields and the dispersion of pollutants. Models purporting to simulate the wind distribution over mountain terrain have been developed from a few different lines of approximation. They all represent some type of compromise, so one must be rather cautious in using them. The compromises chosen by the model developer may not be synonymous with the comprises the user may require. Another point is that models of something as complicated as wind distribution over a large area are not easily validated. Simple indications that the model performs well for a few data points do not suffice because the interaction of multiple factors is too complex in both the model and the actual atmosphere. It is therefore logical for the user to opt for different wind models for differing situations and to remain skeptical about any model results until they are conclusively validated. On a more practical level, a major problem in using a wind model is the complexity of the required input information and the complexity of the user's interaction with the model itself.

To overcome some of these problems, we have developed a system that includes an expandable set of models designed to enable the user to access, condition, and run even complex models with relative ease. The focal point for the system has been air pollution analysis in complex topography. The Topographic Air Pollution Analysis System (TAPAS) is a unified collection of computer application programs that yield meteorological and air quality analyses to support land management decisions. TAPAS application programs simulate wind fields over complex terrain, estimate characteristics of pollutant plumes, identify areas of potential air stagnation, yield map-compatible graphic outputs, and perform other functions. The advantages this system provides are straightforward, economical operation and compatibility of all program inputs and outputs. TAPAS was developed over a number of years with support of the Forest Service and the U.S. Department of the Interior, Bureau of Land Management.

This paper will limit discussion to one wind model (WINDS) and one dispersion model (CITPUFF) within TAPAS.

WINDS Model

The WINDS model is a grid-based, two-dimensional model using the principle of mass conservation. Flow is assumed to be parallel with the topography at the surface. A strong point of the model is that it can accommodate detailed and realistic topography. For example, a major component of TAPAS is a terrain data base containing elevations for every 30 seconds of latitude and longitude for the contiguous United States. These data can be addressed randomly and manipulated to form WINDS model boundary conditions and any other TAPAS outputs desired.

The two-dimensional implementation of WINDS assumes that the wind exhibits the same vertical profile everywhere over the grid. Generally a simple power law is assumed; for example, no change in direction but a change in magnitude. A depth of the surface flow is then assumed; this depth is a major parameter that is set by considering the maximum terrain relief in the domain. The resulting wind patterns are realistic for surface flows in mountainous terrain, particularly when there is between 9 mi/h and 22 mi/h (4 and 10 m/s) driving flow imposed as a lateral boundary condition on the model. A gross mathematical description of WINDS is included in an earlier publication (Fosberg and others 1976), but significant improvements in the implementation of the algorithm have been made through the years (Dietrich and Childs 1984).

WINDS was originally developed to provide the land manager with wind information for planning and analysis in data-sparse areas. The model fulfills practical requirements of operational applications. It is easily applied, economical, and the results seem realistic. WINDS model inputs are easily organized. Wind field outputs are useful alone or as the input to other models.

Wind fields can be presented graphically as velocity vectors, streamlines, or a variety of other representations. A specific example of the WINDS model graphical output is presented later.

CITPUFF Model

CITPUFF is a Gaussian puff model that simulates plume transport and diffusion and estimates pollutant concentrations in complex terrain. Model flexibility allows consideration of a wide range of parameters for multiple point, area, or line sources. Plume calculations account for plume rise, stability, terrain variations, and other characteristics and rely upon the wind fields generated by the WINDS model. Model outputs include time sequences of plume trajectories, dispersion characteristics, and ground-level pollutant concentrations. All outputs are readily translated to map-compatible products.

The basic mathematical formulation of CITPUFF is described in detail in a soon-to-be-published report (Ross and others 1984). It relies on conventional dispersion formulations, although it also allows as a user option the use of rather modern concepts of how dispersion occurs within the planetary boundary layer.

Example of TAPAS: WINDS and CITPUFF Analysis

An analysis performed recently for a prescribed burn conducted by the Bureau of Land Management near Wells, Nev., provides an example of WINDS and CITPUFF model application.

<u>Base map (fig. 3)</u>.--To evaluate the potential effects of the smoke plume on downwind areas, an analysis area was selected surrounding the prescribed burn. The size of the selected area was approximately 1,160 mi^2 (3 000 km^2). Typical TAPAS analysis areas range in size from 770 mi^2 (2 000 km^2) to 7,700 mi^2 (20,000 km^2), depending upon the land management application.

<u>Elevation contour (fig. 4)</u>.--Digital terrain files (30-second grid intervals) for any location in the continental United States can be accessed. Elevation data for the area surrounding the prescribed burn are represented graphically in figure 4. These data were used as inputs to both the WINDS and CITPUFF models. Grid spacings for typical TAPAS applications range from about one-third to one and one-half miles (about one-half to several kilometers), depending upon the land management application.

<u>WINDS model results--wind vectors (fig. 5)</u>.--The prescription for the sample prescribed burn included a wind direction variance of southwest to northwest and a windspeed range of 9 to 13 mi/h (approx. 4 to 6 m/s). WINDS model runs that simulated these conditions were performed. The wind field presented in figure 5 represents the simulation of airflow in the study area under a predominant southwest wind at a moderate speed 11 mi/h (5 m/s). The length of each arrow is scaled to the windspeed. Representative wind fields can be easily integrated into the analysis.

<u>CITPUFF results covering the range of prescription conditions</u>.--Figure 6 is a representation of three potential plume trajectories under southwest, west, and northwest winds at 11 mi/h (5 m/s). For modeling purposes, plumes can be represented by discrete "puffs." CITPUFF results can be represented as plume trajectories (trajectories coupled with dispersion characteristics) or ground-level pollutant concentration contours. The puffs plotted in figure 6 are the actual position of puffs released every 10 minutes. Their radius is defined as 2 standard deviations of the pollutant distribution.

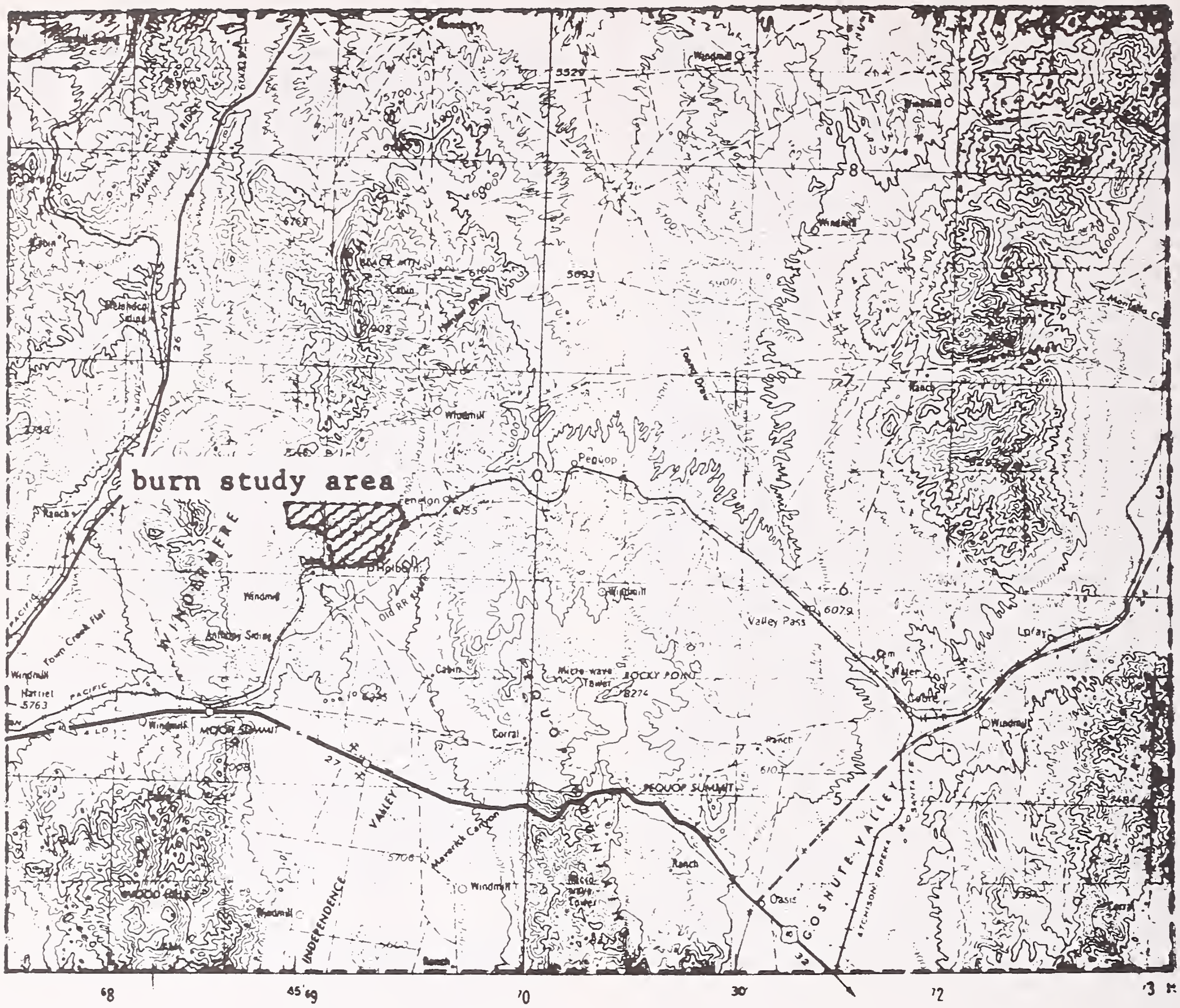

Figure 3.--Base map for prescribed burn study area near Wells, Nevada.

Figure 4.--Computer-based elevation contour map of the prescribed burn analysis area.

<u>CITPUFF results for actual burn conditions (1500 local time)</u>.--Figure 7 represents the plume trajectory at 1500 on the burn date. The plume rose approximately 5,000 feet (1 600 m) above the ground and was transported by a wind from the west-southwest (260° at 13 mi/h [6 m/s]). Aircraft and surface observations at 1500 verified the location of the modeled plume trajectory. The figure indicates where aircraft observations located the center (c) and northern boundary (e) of the plume.

DISCUSSION

The tools identified should provide information about the meteorological environment of wilderness and, therefore, for planning and possibly operational aspects of wilderness fire programs. These experimental and analytical techniques have been developed with the objectives of cost control, timely outputs, and utility in mind. Considerably more needs to be done, however. These tools are

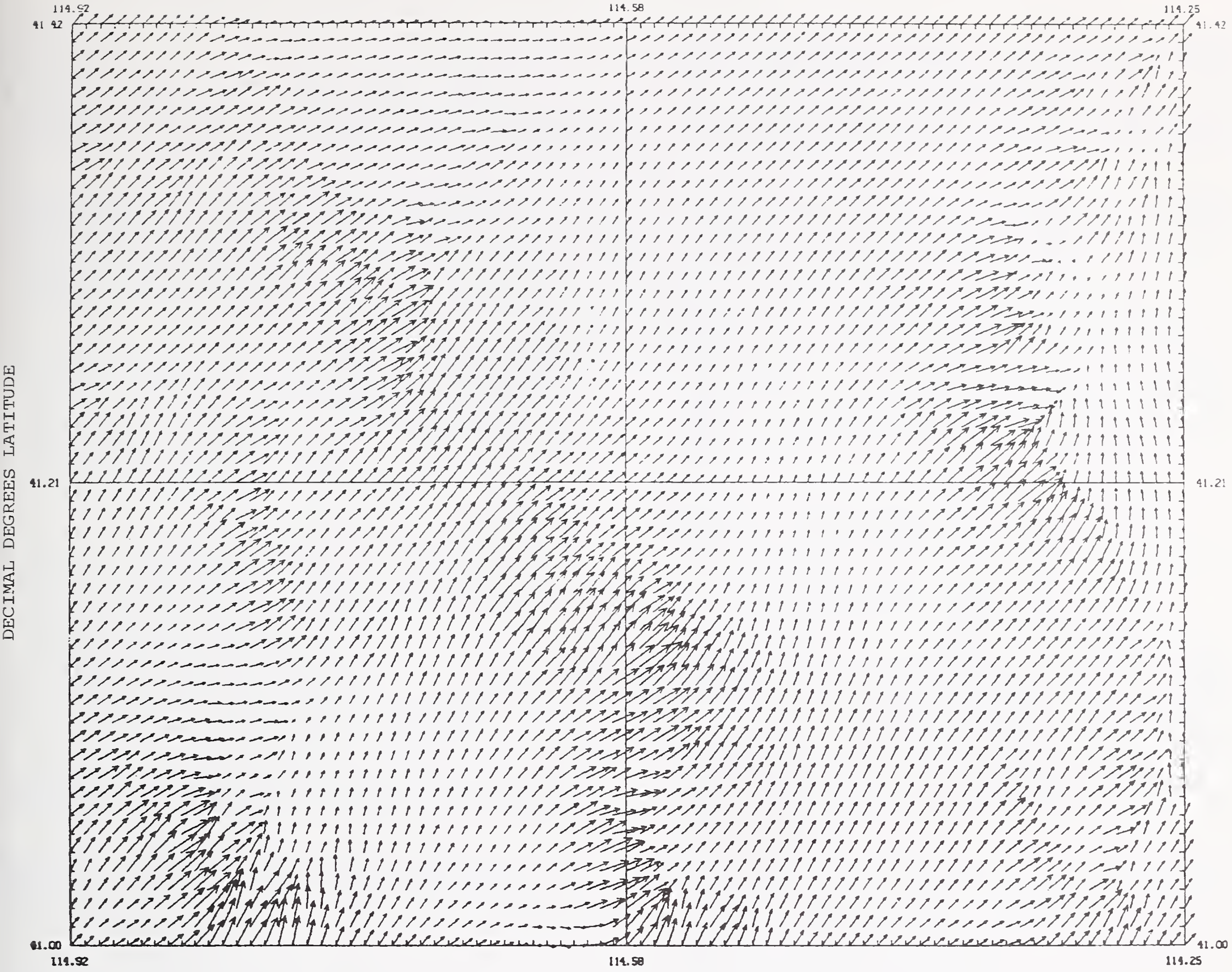

Figure 5.--Wind field simulation (WINDS model) results for an influencing southwest wind flow at 11 mi/h (5 m/s).

currently being used to access potential air quality impacts on wilderness areas in the Western United States (Dietrich and others 1982). They have been used to develop wind atlases and wind climatologies for various purposes (Dietrich 1981). They have also been used to site weather stations in mountainous terrain.

The results shown in the example are from the first explicit application of these tools to a fire situation. Many problems remain in determining just how useful they might be.

Technical problems with the modeling include properly determining the smoke emission factors for natural fire, determining the effects of natural canopy on smoke emission, and validating the various wind and dispersion models utilized within the system. Use of the measurement tools, associated with some actual situations, should lead to increased confidence in the utility of both the measurement and the models. On a less technical plane, the managers must be properly equipped to deal intelligently with this information.

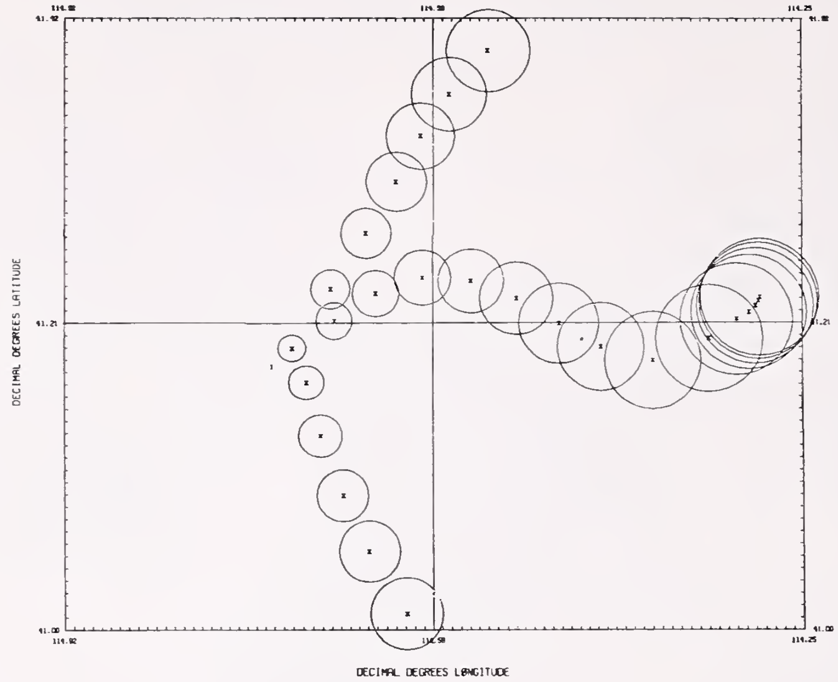

Figure 6.--Combined plume trajectory simulations (CITPUFF results) for three influencing wind directions: northwest, west, and southwest.

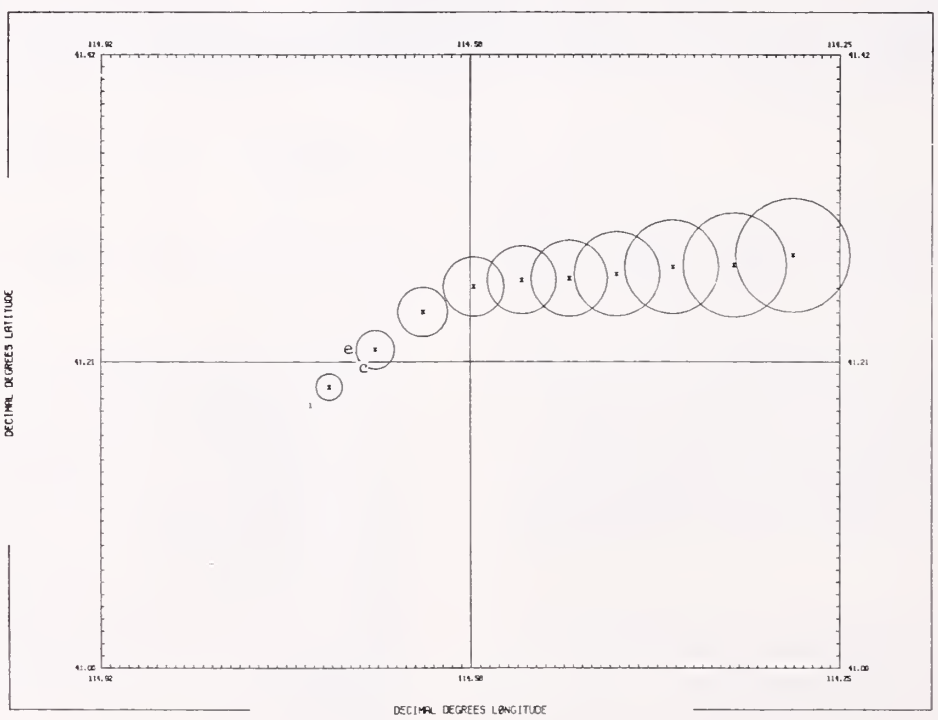

Figure 7.--CITPUFF model plume trajectory results for actual Holburn burn conditions (1500 local time).

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IN PROGRESS: A MISSION MOUNTAIN TRIBAL WILDERNESS FIRE PLAN

Joseph Glassy

ABSTRACT: A fire management plan is being prepared for the Mission Mountain Tribal Wilderness. Discussion includes the fire management planning process, a description of plan objectives, the classification of the wilderness into fire management zones, the formulation of fire management prescriptions, and baseline data needs. Two planning considerations unique to the area are the cooperative administration of the area by the Confederated Salish and Kootenai Tribes and the U.S. Department of the Interior, Bureau of Indian Affairs, and the effect of the area's narrow configuration on the development of fire management prescriptions.

INTRODUCTION

Land managers are becoming increasingly aware of the role fire plays in Northern Rocky Mountain ecosystems. Fire has long been used as a valuable tool for managing commercial timber stands and for nearly a decade has been allowed to resume a more natural role in some wilderness areas.

In Montana, the precedent has been set for returning fire to these ecosystems. Currently the U.S. Department of Agriculture, Forest Service, has operational wilderness management fire plans for several areas, including the Selway-Bitterroot, Cabinet Mountains, Lincoln-Scapegoat, Anaconda-Pintler, Absaroka-Beartooth, and Bob Marshall Wilderness Areas. Because the development and implementation of these fire plans have produced valuable experience, other agencies that manage wilderness (such as the U.S. Department of the Interior, Bureau of Indian Affairs and the Bureau of Land Management) are now becoming interested in developing similar plans.

Earlier this year the Bureau of Indian Affairs (BIA) decided to develop a wilderness fire plan for the 94,000-acre (37 600 ha)tribal wilderness area located in the Confederated Salish and Kootenai Indian Reservation in western Montana. This wilderness area contains diverse ecosystems ranging from steep, rocky alpine zones to milder midelevation zones. Because the Mission Mountain Tribal Wilderness Fire Plan is in an early stage of development, some of the more detailed planning elements mentioned here may change.

Paper presented at the Wilderness Fire Symposium, Missoula, Mont., November 15-18, 1983.

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THE FIRE PLANNING PROCESS

The process I am using is an adaptation of the general methodology used by the Forest Service. It incorporates refinements resulting from over a decade of wilderness fire planning experience. Fischer (in press) provides a valuable statement of this process, describing both a philosophy and a structure inherent in a sound wilderness fire management plan. His guidelines follow the general organizational structure of the National Environmental Protection Act (NEPA) planning requirements.

Although the Mission Mountain Tribal Wilderness is not a component of the National Wilderness Preservation System (NWPS) and is not strictly subject to the NEPA planning requirements, the NEPA planning outline remains a useful tool for developing this plan because it contains many "common sense" elements relevant to any planning process. The NEPA philosophy also encourages a wider perspective regarding the role of a wilderness fire management plan in the context of the tribal wilderness management plan (Rockwell 1980). A wilderness fire management plan is the lowest level plan in the overall land management planning hierarchy and as such should respond to policies described in higher level plans like the tribal wilderness management plan.

Fire is a significant agent of change in almost all Northern Rocky Mountain ecosystems, with much of its significance stemming from the diversity of resources it affects. In an attempt to respond to these interrelated effects, the Mission Mountain Wilderness Fire Plan incorporates an interdisciplinary approach in its development and implementation.

WILDERNESS FIRE PLAN OBJECTIVES

The objectives of this plan, listed below, resemble those of many Forest Service wilderness fire plans now in operation.

1. Maintain vegetative mosaics resulting from fire.

2. Maintain plant and animal relationships that have evolved with fire.

3. Maintain genetic traits that have developed in response to fire.

4. Maintain dead and live fuels in a natural state of continuity, depth, arrangement, and loading.

5. Demonstrate that fire is a natural and essential component of wilderness ecosystems.

In support of the wilderness management plan and other tribal policies, the following situations will necessitate immediate fire suppression action:

1. Fires that are human caused.

2. Fires that threaten private land, human life, and/or property.

3. Fires projected to cause physical damage to administrative, historical, or archeological sites or structures.

4. Fires that threaten nonwilderness lands or resources.

5. Fires occurring where management plan prescriptions are exceeded at ignition time.

FIRE MANAGEMENT ZONES AND UNITS

After a thorough analysis of the wilderness land base, fire management zones, broken up into smaller units where necessary, are defined for the wilderness area. These units provide a coherent structure for classifying similarly managed land parcels. Criteria for the classification of these zones and units are developed on the basis of natural and political land features, fire behavior potentials, and environmental gradients such as ecological life zones. Aerial photographs, color orthophotos, and ground-truth data are used to describe and transfer these stratifications to planimetric and topographic maps that are included in the plan.

Each fire management zone contains directions for the following:

1. Fire detection--scheduling and routes for the aerial fire patrol and the use of fixed lookouts and cooperative detection agreements.

2. Fire prevention--visitor contacts, signs, and other prevention program materials.

3. Presuppression--pre-attack data keyed to areas, including fire behavior potentials and availability of water and spike camp locations.

4. Fire prescriptions--dispatch and response to all fire starts.

FIRE MANAGEMENT PRESCRIPTIONS

The fire management prescriptions are the "executive arm" of the fire plan; they translate the objectives and constraints listed previously into a set of practical guidelines specific to the fire management zones and units. In general, there is at least one fire prescription per fire management zone. Except for constraint elements, these prescriptions do not necessarily constitute hard and fast policies.

As state-of-the-art fire management technology advances, there may be a temptation to rely too heavily on the sophisticated tools available rather than on the experience of local fire managers. The fire prescriptions should be primarily used to provide a sound basis for decisions by the Fire Management Committee, not as a "cookbook" that makes automatic decisions possible.

FIRE PLAN BASELINE DATA

In addition to existing literature and data available on the tribal wilderness area, other baseline fire data are collected. An extensive ground survey is conducted to gather representative data on the fuel complex and relative fire behavior potential of the area. Although some traditional fuel inventory plot data are collected, the survey relies heavily on the photo guide series for appraising downed woody fuels (Fischer 1981). All data are summarized in tables and graphs within the plan.

To help provide a basis for establishing a preferred "natural" fire regime for the area, a limited fire history reconnaissance of the area is conducted using the Arno and Sneck (1977) technique which helps establish historical fire frequencies and intensities.

SPECIAL CONSIDERATIONS

Several combined management considerations make this wilderness fire management planning effort unique. The wilderness area generally conforms to the midslopes and crest of a long, narrow mountain range bordered on one side by the Flathead valley (largely private agricultural land) and on the other by a section of wilderness managed by the Forest Service. This configuration necessitates anticipating the possible spread of tribal wilderness fires into nonwilderness areas, into wilderness managed by the Forest Service, and into State lands on the southern border. Superficial evidence of past fires in the area indicates typically long and narrow runs up steep slopes, ending in subalpine cirques and glaciated valleys. Because the crest of the range is somewhat buffered by other wilderness lands, the greater concern is the probability of downslope spread of fires starting higher up. Fire prescription preparation depends on a thorough analysis of these probabilities.

Another unique consideration involves the way the tribal wilderness is administered. The Confederated Salish and Kootenai Indian tribes are ultimately responsible for administering the tribal wilderness area. Responsibility for the fire management of the area, however, rests with the Bureau of Indian Affairs. This administrative

partnership necessitates close cooperation in formulating and implementing fire management policies for the wilderness area.

Public support for fire management policies (especially those involving the return of fire to some ecosystems) has long been recognized as crucial to the success or failure of modern fire management plans (Stankey 1976). One approach to help assure early public involvement in the fire planning process is to distribute informational material stating the plan's goals along with a request for responses to the situation. Mutch (1983) uses this method in developing fire management alternatives for the River of No Return Wilderness Area in Idaho. An adaptation of this technique will probably be used in developing the Mission Mountain Wilderness Fire Plan.

CONCLUSION

This tribal wilderness fire management plan represents a pioneer effort by the Bureau of Indian Affairs, even though many similar plans exist for Forest Service areas. The fire management programs of other tribal wilderness areas administered by the BIA may be influenced by the relative success of this fire plan.

In addition to meeting ecologically related objectives such as allowing fire to resume a more natural role in wilderness, fire plans such as this may help reduce fire suppression costs in tribal wilderness areas. The current policy is to unilaterally suppress all fires within the Indian Reservations, including those in wilderness. As confidence is gained in the ability to implement a tribal wilderness fire management policy, the cost of many of these wilderness fires may be reduced to the nominal cost of surveillance for much of the fire season.

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COEVOLUTION OF NATIONAL PARK SERVICE FIRE POLICY AND THE ROLE OF NATIONAL PARKS

David M. Graber

ABSTRACT: Fire policy depends upon the function served by a unit of land and the land manager's perception of fire's role in that function. The role in society played by national parks containing large natural areas has evolved saltatorially over the 111 years since Yellowstone National Park was created. Early policies emphasized management of the scene that existed when Europeans first arrived. Present policy emphasizes management for unimpeded natural processes. Each state in the evolution of society's attitudes toward national forests has altered and will continue to alter National Park Service fire policy.

INTRODUCTION

Changes in the management of fire in national forests have always been closely affiliated with changes in the perceived function of those forests. Timber production, grazing, recreation, promotion of wildlife, and wilderness preservation are goals that elicit different fire management programs. Given present-day knowledge of fire ecology and fire husbandry techniques, selecting the appropriate fire management program is a relatively straightforward process. For the U.S. Department of the Interior, National Park Service, goals have never been so clear-cut.

The Yellowstone Act of 1872 created a "public park or pleasuring ground for the benefit and enjoyment of the people" in which "the natural curiosities or wonders" were to be maintained "in their natural condition." By 1916, when Congress created the National Park Service through additional legislation, more visionary language directed the new agency "to conserve the scenery and the natural historic objects and the wildlife therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations" (National Parks Act of 1916)

ERA OF SPECTACLES

From 1886 to 1916, when the U.S. Army administered the national parks, and for the first 50 years of National Park Service management, the mandate from Congress was interpreted in a way that excluded fire (Pyne 1982). In fact, the first generation of national parks was selected for its scenery and spectacles: geysers, waterfalls, big trees, deep canyons. Protection of these phenomena and their immediate environment and of visitors and their enjoyment of the scenery was Park Service policy and was taken directly from the 1916 law. The policy was translated to mean fire exclusion. That fire suppression in some areas creates its own long-term threat to safety and scenic resources was not yet appreciated. During this period, the Park Service lacked the professional cadre and mutally reinforced shared values already well developed in the U.S. Department of Agriculture, Forest Service (Pyne 1982). In most cases it was the Forest Service that planned and conducted firefighting in the national parks. Park Service firefighting did not come into its own until the 1930's.

The management of national parks for protection of natural features and for the pleasure of visitors led to tourist accommodations directly abutting those same features and the creation of new amusements such as bear feeding stations and the famous Yosemite firefall. To protect living scenery, forest insects and diseases were fought with pesticides and prophylatic cutting without regard to whether the phenomena were natural, exotic, or aggravated by human presence (Ise 1961). Management of wildlife was largely an ad hoc affair. Although traditional Park Service policy long has been "to permit each species of wildlife to carry on its struggle for existence without artificial help" (Ise 1961), individual superintendents regularly ordered reductions of hoofed animals when they were believed to be overstocked or damaging vegetation.

Thanks to work by scientists such as Adolph Murie and George Wright, the policy of destroying predators to increase ungulates or because their activities were offensive to some was gradually abandoned in the 1930's (Wright and others 1933). By the end of the decade, authors of internal documents (Dixon 1940) and popular articles (Finley and Finley 1940) were questioning the Park Service habit of feeding bears and of killing them when they become nuisances. But despite valuable advice from people within and outside the agency, it lacked a substantive resource policy. Furthermore, no professional scientists and resource managers were available to give life to such a policy.

Paper presented at the Wilderness Fire Symposium, Missoula, Mont., November 15-18, 1983.

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ERA OF RESOURCE MANAGEMENT

National park resource management entered a new age when an advisory board on wildlife management appointed by then Secretary of the Interior Stewart Udall filed its 1963 report entitled "Wildlife Management in the National Parks" (Leopold and others 1963). The Leopold Committee far exceeded its formal directive and produced a document that spoke to the broad issue of goals and policies for natural resource management in the national parks. Its words were transformed into official policy:

> As a primary goal, we would recommend that the biotic associations within each park be maintained, or where necessary recreated, as nearly as possible in the condition that prevailed when the area was first visited by the white man. A national park should represent a vignette of primitive America.

With this goal clearly and formally stated, the committee said that means to achieve it could include reintroducing extirpated species, controlling or eliminating exotics, and managing population where natural controls or park size and necessary habitat components were inadequate. Although time and patience might restore climax communities disrupted by fire, logging, or other disturbances, the loss of seral and other fire-dependent communities could only be restored by reintroducing fire. For the Sierra Nevada of California, the report specifically recommended controlled burning as the only method that could extensively reduce "a dog-hair thicket of young pines, white fir, incense cedar, and mature brush --a direct function of overprotection from natural ground fires."

The committee restated views enunciated in 1962 at the First World Conference on National Parks; there it had been suggested that park management served a homeostatic function, substituting artificial controls for natural ecologic factors that had been lost on account of inadequate park size, extirpation, or human activities over time. The Leopold Report stressed the management of a scene and defined that target scene explicitly as the moment when Europeans first laid eyes on it. "A reasonable illusion of primitive America could be recreated, using the utmost in skill, judgment, and ecologic sensitivity."

Possibly the most far-reaching recommendation of the Leopold Committee (1963) was to develop a professional cadre of scientists and resource management specialists within the National Park Service:

> Active management aimed at restoration of natural communities of plants and animals demands skills and knowledge not now in existence. A greatly expanded research program, oriented to management needs, must be developed within the National Park Service itself. Both research and the application of management methods should be in the hands of skilled park personnel.

The Leopold Report at last provided a rationale for managing natural or wilderness areas in national parks. It called for acquiring scientific information so that the "vignette of primitive America" could be determined and the tools best able to restore it selected. It repeatedly specified controlled burning as a preferred tool for manipulating vegetation because of its low cost and its ability to simulate the effects of wildfire.

Those familiar with the writings of John Muir know that his descriptions of open stands of conifers on the western slopes of the Sierra Nevada and his reports of frequent fires set by local Indians (and by this time ranchers as well) conflicted sharply with conditions in Yosemite and Sequoia National Parks in the latter 20th century. Reports by Hartesveldt and his co-workers (Hartesveldt and Harvey 1967; Hartesveldt and others 1975) found a classic example of fire dependence in the giant sequoia (*Sequoiadendron giganteum*). The era of suppression apparently had drastically reduced reproduction while encouraging undergrowth that jeopardized the famous giants when fire did--inevitably--recur. Biswell (1967) provided the technical basis for fuel reduction by prescribed fire, and the National Park Service at last felt it had the policy imperative, the biological justification, and the technical skills to introduce this management technique. As Pyne (1982) reports, early successes in the Sierra Nevada emboldened resource managers, and the 1970's were years of great experiments with prescribed fires in several national parks. In some of these, enthusiasm unfortunately exceeded fire management techniques or a full understanding of the ecological consequences.

The Park Service had two distinct reasons for introducing prescribed fire into its natural areas. The first was that nearly a century of fire suppression presumably had altered pristine plant communities. The second was that buildup of both living and dead fuels constituted a threat of unnaturally hot and dangerous wildfire that imperiled park resources, people, and surrounding lands. These threats and their solution through prescribed fire rapidly became incorporated into management documents (for example, van Wagtendonk 1974; Sequoia and Kings Canyon National Parks 1979). Fires produced by natural ignition sources were permitted to burn with increasing frequency, but only insofar as they were in prescription and furthered management objectives. As natural areas were modified by prescribed fire, managers felt the reduced fuel loadings would permit larger proportions of the parks to be included in natural fire zones. Both natural and prescribed fire, however, were intended to serve the same end: restoring and perpetuating Leopold's "vignette of primitive America."

Evidence continues to accumulate that, throughout much of the world, aboriginal humans greatly influenced vegetation by burning (Pyne 1982). This appears to be true of California, including the Sierra Nevada (Lewis 1973). When Kilgore and Taylor (1979) reconstructed the fire history of

sequoia-mixed conifer forest, they found a fire frequency substantially greater than one that could be generated by contemporary natural ignition rates and concluded that Indians were responsible for a large but undetermined proportion of the fire scars they found. Partly because it is now difficult to distinguish the historic effects of aboriginal burning from those of lightning-caused ignitions, and partly because the Leopold Report specifically referred to "the condition that prevailed when the area was first visited by the white man" (from which one may infer that Indians were to be included in that landscape), managers in the Sierra Nevada parks have been inclined to merge both ignition sources and their ecologic effects when calculating "natural" vegetation patterns and developing prescribed burning plans. Similar Indian burning effects have been noted and similar management conclusions drawn for other areas, such as the Northern Rocky Mountains (Barrett and Arno 1982).

Under the Leopold approach, resource managers in a growing number of western parks with significant natural or wilderness areas have made their first step to restore vegetation structure to what it was in presettlement times, generally defined as approximately a century ago. In most cases that structure has been estimated from present stand structure, fire scars and other physical evidence, historical records, and inferences drawn from similar vegetation elsewhere. All of these techniques--except rare instances where actual reports of Indian burning frequency and extent are available--lump ignition sources for past fires. A combination of mechanical manipulation and prescribed fire has then been applied. Although not always explicitly stated, program objectives for the "first round" of burning programs generally include (1) restoring the presettlement scene; (2) protecting visitors, structures, featured resources, and designated scenery; (3) preventing, as an outcome of ignition from any source, uncontrolled wildfire that could burn areas within or outside park boundaries in an unacceptable fashion. The rationale for this approach is fully developed by Parsons (1981).

As techniques for burning have developed to the point where first-round fire management programs can be implemented successfully, managers have been confronted with the dilemma of where to proceed next. In natural areas, one is left with the alternatives of ceasing prescribed burning and permitting natural ignitions to provide the sole source of fire, or supplementing/supplanting natural ignitions indefinitely with prescribed fires whose parameters would be determined by available information on presettlement fire behavior, present and historic vegetation structure, or both. In practice, the first alternative is unlikely ever to be implemented strictly: protection of various resources and conflicting fire policies on adjoining lands will require prescribed fire for reasons other than ecological objectives. The second alternative is obligatory if Indian burning was a significant factor in creating the presettlement scene.

ERA OF ECOLOGICAL RESERVES

As other wild ecosystems are compromised by a variety of human activities, such as mining, grazing, logging, and recreation, those that are left untouched become increasingly valuable as living laboratories of natural ecological processes. Their value as controls in a world where human influence is virtually omnipresent varies inversely with the degree to which they disturbed. This newly emphasized function of natural areas is explicitly recognized by the dedication of International Biosphere Reserves under UNESCO's Man and the Biosphere Program. American biosphere reserves include not only national parks but also land managed by other agencies and include both natural and manipulated sites (Risser and Cornelison 1979).

For the National Park Service, recognizing the scientific values of natural or wilderness areas introduces some conflicts with other uses. Human visitation, which is already acknowledged to compromise wilderness value when it reaches certain levels, may significantly compromise scientific value at yet lower levels. Collection of scientific information often includes setting up scientific equipment, destructive sampling of resources, and other visual or acoustic blights on an otherwise unmarred landscape. For the National Park Service, these conflicts remain unresolved at the policy level.

The Leopold approach of scene management is incompatible with management for unimpeded natural processes. By designating a particular set of conditions a "reasonable illusion of primitive America," and calling upon both natural and artificial processes to achieve it, new anthropogenic artifacts--however subtle or artful--are introduced into the system and compromise any study of natural processes. An alternative approach recognizes, as did the Leopold Committee, that parks are ecologic islands and cannot be managed as limitless wilderness. It still requires revising or mitigating anthropogenic effects in natural areas. But by abandoning the notion of an end product--the "correct" scene--natural processes are permitted to proceed unimpaired within previously stated constraints of protection of life, property, and designated resources. This new perspective recognizes that ecosystem processes and ecosystem elements are both real properties, that they are interdependent, and that both are valid and important objects of study.

The natural process approach to wilderness management obviates some difficulties with the Leopold model and introduces a few of its own. Cycles and trends in climate, erosion, and plant succession no longer pose as management issues; they can be observed rather than confronted. Wildlife population phenomena such as epizootics, irruptions, and collapses likewise are no longer at issue. What once were problems are now phenomena. Simulation of aboriginal burning is inappropriate because it

freezes a moment in Indian cultural evolution, climate, and biotic relations for all time. Had they been free to follow their own cultural destiny, Indians presumably would not have pursued deer, collected acorns, and ignited fires in perpetuity.

Bonnicksen and Stone (1982) elucidate some of the inherent contradictions in what they call "structural maintenance objectives" and point out the interdependence of structure and process. They claim that in the Sierra Nevada sequoia-mixed conifer forest, changes in forest structure produced by decades of fire suppression have now sufficiently altered fire behavior so that fire/forest interactions with or without simulated Indian burning do not follow the pattern that would have prevailed had Europeans never entered the scene. Bonnicksen and Stone focus on relatively short-term phenomena and ignore long-term variations in forest and fire produced by climatic cycles that could far outweigh human influence.

A serious difficulty in permitting unimpeded natural processes in national park natural areas is that knowledge of anthropogenic factors to be corrected is poor. Lacking data on long-term lightning ignition and spread patterns, one cannot compensate for loss of fires that previously invaded from beyond park boundaries. When ungulate populations explode and collapse, is it from loss of predators or habitat beyond park boundaries or a natural phenomena? That kind of information can be obtained only by scientific study of the phenomena. The study of wildfire pattern and process is itself valid, but it requires repeated observation of the phenomena in question. National park wildernesses have fewer confounding variables than most other sites.

A greater obstacle may be that wildfires include high-intensity and extensive conflagrations that are frightening, dangerous, and unpopular. Evolving fire management techniques may eventually permit more frequent containment and less outright suppression of chaparral fires and forest crown fires, but until then lower intensity partial simulations must suffice. In the many locations where fuel buildup from fire suppression would produce an unnaturally hot wildfire, prescribed fire remains the necessary first step.

The ecological reserve approach to national park wilderness and natural areas is compatible with the Wilderness Act of 1964 and the philosophy behind the Act as developed by Nash (1978). The role of fire in park wilderness is substantially that described by Heinselman (1978). National parks have traditionally emphasized the recreational use of wilderness for its esthetic and spiritual value, a policy that is largely harmonious with the parks' value as reserves of wild natural objects and processes from which we may learn more about the world and how we are changing it.

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FIRE HISTORY AND ECOLOGY OF FOREST ECOSYSTEMS IN KLUANE NATIONAL PARK--FIRE MANAGEMENT IMPLICATIONS

Brad C. Hawkes

ABSTRACT: A study of the fire history and ecology of the Kluane National Park's (KNP) forest ecosystems was undertaken to facilitate development of a fire management plan. The park was classified by Rowe in 1972 as the Kluane Section (B.26d) of the Boreal Region to determine the ecological role of fire in vegetation renewal and succession.

Results of the study indicated that lightning is an infrequent ignition source in KNP. Human-caused fires were important in vegetation renewal, especially since the late 1800's, as indicated by the difference in fire frequency between remote study areas within the park and those heavily used by humans. The present vegetation moasic is partially the result of human-caused fires (early Europeans and native Indians) and supports many varieties of wildlife. Glacial movements have also produced vegetation renewal and succession by exposing new material and causing lake formation and drainage.

The fire management strategies developed by Parks Canada for KNP should consider these vegetation-cycling mechanisms. Decisions will be made as to what vegetation mosaic Parks Canada will perpetuated as "the natural resources within the Park" (Parks Canada 1979). If only lightning fires are considered for recycling vegetation, the average age of forest stands will increase and plant species will change--for example, trembling aspen (*Populus tremuloides* Michx.) will be succeeded by white spruce (*Picea glauca* [Moench] [Voss]), and vegetation mosaics will become less diverse.

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CHANGES IN FUEL LOADING AND FIRE BEHAVIOR AROUND MOUNT ST. HELENS, WASHINGTON

Robert E. Hogfoss and Edwin A. Brown

On May 18, 1980, the lateral blast of Mount St. Helens created tens of thousands of acres of blowdown timber and thousands more of standing dead fringe surrounding the blowdown. Lightning and heat generated by the eruption started fires in several areas around the volcano, but heavy ashfall, followed by several weeks of rain, extinguished many of the fires. Subsequent eruptions deposited more ash over the area, but hundreds of small fires continued to burn, smoldering slowly from log to log beneath the ash.

Suppression actions in 1980 were limited because of restricted access and hazards near the affected area. By the end of 1980, however, it was clear that fire danger around Mount St. Helens was not high, at least for the short term. The initial eruption disintegrated or buried virtually all of the fine fuels. Although the eruption created large areas of heavy fuel loading, the ash layer removed fuel continuity and retarded fires that were ignited.

Scores of isolated small fires continued to burn in 1981, but no further ignitions occurred. Existing fires were monitored throughout the summer, and a fuels study was begun. Salvage logging operations began in 1981 and continued through 1982, breaking up large blocks of blowdown and fringe. In the fall of 1982, Congress created the Mount St. Helens National Volcanic Monument (110,330 acres [44 650 ha]), placing more than 26,000 acres (≅10 500 ha) of blowdown and over 5,000 acres (≅2 000 ha) of fringe in a protected status. More than 35,000 acres (≅14 100 ha) of general forest were also included in the Monument boundary.

Observations made in the blowdown and fringe between 1980 and 1983 revealed some significant changes in fuel characteristics. Ash has by now eroded or settled in all areas, exposing many of the fuels previously covered. Wind and snow have begun to strip remaining branchwood in the fringe, adding to the fuel load. Wind effects have been most pronounced on steep slopes, where breakage in some areas has increased fuel loads from nothing in 1980 to over 23 tons/acre (62 tonnes/ha) in 1983 for the less than 3-inch (7.6-cm) size class.

Revegetation has begun in all areas, progressing most rapidly in the fringe. Species composition is similar to the regeneration occurring after a high-intensity fire, and new litter is accumulating over the ash.

Fire behavior in slash burns adjacent to the blast area is greatly affected because the fuels are lying directly upon ash and pumice. Ash absorbs moisture and increases reflectivity, leaving these ground fuels drier and warmer than usual. Consumption of less than 3-inch (7.6-cm) fuels has been over 94 percent, even where total fuel loads have been light and discontinuous.

Fuel loading as of October 1983 averages from 81 to 133 tons/acre (220 to 362 tonnes/ha) in the fringe, and from 148 to 232 tons/acre (403 to 632 tonnes/ha) in the blowdown. Less than 3-inch (7.6-cm) fuels average from 7 to 13 tons/acre (19 to 35 tonnes/ha) in the fringe and from 2 to 4 tons/acre (5 to 11 tonnes/ha) in the blowdown.

Work is underway to develop a comprehensive management plan for the Monument. Although a preferred alternative has not yet been selected, the Monument legislation requires that the area be managed for "preservation of the natural geologic and ecologic processes and integrity of the resources." The general management approach will resemble that used in wilderness areas or national parks. The desired role of fire will likewise be similar to that used in wilderness areas, but the unique environment and an anticipated high visitor use will require a wide range of fire management strategies.

Selection of the preferred alternative for the management of the Monument is due by mid-summer 1984; a fire management plan will also be completed in 1984.

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REPORT FORMS FOR PRESCRIBED UNPLANNED IGNITION[1]

Frank E. Lehto

ABSTRACT: Resource managers' increased emphasis on restoring fire as a primary force of nature to achieve ecological succession has resulted in several operational problems. One of these problems is the lack of a uniform procedure for reporting prescribed fire from unplanned ignitions.[1] Several Forest Service Regions are utilizing the 5100-29 Individual Fire Report to meet this need; however, this report is strongly oriented toward wildfire suppression. The limited information available on the individual Fire Report does not cover the various aspects of these prescribed fires. Many additional items of information are needed to evaluate the program, such as funds expended for monitoring, number of person-days spent in monitoring, types of conditions the fire burned under, and total acres burned. This information is necessary, not only for future planning, but to answer inquiries concerning this new and highly visible change from our historic fire policy. The Pacific Northwest Region of the Forest Service has developed an interim reporting form to document the occurrence of prescribed fire from unplanned ignitions. This form is structured for use as an automated data base and uses many of the same codes specified for the 5100-29 in the Forest Service Handbook 5109.14.

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[1]Editors' note: Please refer to the Foreword for comments on prescribed fire terminology.

FOREST AND RANGELAND FIRE HISTORY BIBLIOGRAPHY

Ronald J. Mastrogiuseppe, Martin E. Alexander, and William H. Romme

A bibliography dealing with the subject of wildland fire history was first published in December 1979 by the second author of this paper (Alexander 1979). A supplement to the original bibliography was included in the proceedings of the Fire History Workshop held October 20-24, 1980, in Tucson, Ariz. (Alexander 1980). The authors have continued to monitor the expanding literature on forest and rangeland fire history, thus adding to the initial bibliography and supplement. The most recent version of the bibliography was reproduced by the U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station's Fire Effects and Use Research and Development Program, Northern Forest Fire Laboratory, Missoula, Mont., for distribution at the Wilderness Fire Workshop and Symposium (Mastrogiuseppe and others 1983).

This updated bibliography consists of 485 references dating back to 1900, although over 70 percent of the entries date from 1970. The subject matter focuses chiefly on dendrochronology (tree-ring and fire scar dating), palaeoecology (charcoal analysis of lake sediments), and historical geography (written accounts of wildland fires). The primary geographical emphasis is North America; but a limited number of international references, largely from Fenno-Scandia, are included. An area index organized by province, state and country is keyed by author(s) and publication date to the alphabetical list of references.

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The primary purpose of these bibliographies has been to compile all relevant published references and significant unpublished reports as an aid to resource managers and environmental scientists. The complete bibliography is now maintained on a computerized file to facilitate ease of revisions and the printing of up-to-date versions. Maintenance of a complete and accurate bibliography is a continuing project. The authors would appreciate being notified of any errors, omissions, suggested deletions, etc. All correspondence should be directed to the senior author at the following address:

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FIRE PLANNING INFORMATION FOR REMOTE AREAS OF ALASKA

Melanie Miller

Fire management planning is included in the resource management plan being prepared by the U.S. Department of the Interior, Bureau of Land Management (BLM), for the Central Yukon Planning Area, 9.4 million acres (3.8 million ha) of public lands in west-central Interior Alaska. The Tozitna and upper Melozitna River Valleys and Ray Mountains typify BLM lands in the planning area in that they are remote, roadless, and essentially uninhabited. Potential for commercial use of natural resources is low. Many of the lower elevation areas have burned since the 1950's, and most fires have been lighting caused. Major fuel types are pure black spruce or combinations of aspen, paper birch, and white spruce; shrub tussock tundra; and alpine communities.

Fire history information is limited to computerized fire occurrence records from 1956 to the present, with fire reports available for most years. Detailed fire maps are frequently not included in fire reports. Computer-generated fire occurrence overlays for 1:250,000 scale maps (the standard scale used for planning) show fire origin, number, and fire years. Fire boundaries have been plotted from existing maps of fires larger than 5,000 acres (≅2 000 ha). Although 1:60,000 scale color infrared photography is available and can provide site-specific fuels information, it is unwieldy for use with vegetation and fuels information for such a large area.

Landsat satellite data have been quite valuable for expanding the data base. Black and white scenes have been used to determine the exact location and perimeter of fires from the late 1960's and early 1970's because fire maps are not available for this period. The most important use of Landsat data for the planning effort has been to derive fuels information through the use of computer enhancement techniques. An enhancement is made by reassigning the narrow range of numerical values in which vegetation is recorded to a much broader range. A colored photographic image can be produced on which major fuel types can be readily differentiated, as well as unvegetated alpine ridges, deciduous or spruce stringers, and narrow riparian zones.

Enhanced Landsat images may be useful wherever vegetation is represented by several major contrasting types. Costs are much lower than for a computer classification of Landsat data. Although a digital data base is not produced, an image is obtained from which fuel types can be mapped at a scale suitable for fire planning.

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TECHNIQUE FOR FACILITATING MONITORING AND EVALUATION OF PRESCRIPTION FIRE

Francis Mohr

ABSTRACT: A form for recording and displaying prescription fire data facilitates the monitoring and evaluation of prescription fire. Measured environmental elements and observed fire behavior are consolidated on one page.

Advantages are:

1. A format that permits easy recording and displaying of data during the burn.

2. Easy and quick monitoring to determine whether the burn is within prescription limits.

3. A permanent document with data that are highly legible and quickly comprehended for evaluation purposes.

4. A quick visual reference for comparing prescribed fire data and resulting effects when planning or implementing additional prescription fires.

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INFORMATION NEEDS FOR NATURAL FIRE MANAGEMENT PLANNING[1]

David Parsons, Larry Bancroft, Thomas Nichols, and Thomas Stohlgren

ABSTRACT: The development and implementation of an effective natural fire management program require a clear definition of goals and objectives, an ever-expanding information base, and effective program evaluation. Examples are given from Sequoia and Kings Canyon National Parks.

INTRODUCTION

It has been well documented that fire plays an important role in maintaining many natural ecosystems (Heinselman 1978; Pyne 1982). When management policy calls for protecting or preserving a natural area, local managers often must use fire to achieve specific objectives. Although the specifics of such objectives may differ with the goals of the area, they always require a systematic, well-documented management strategy. The development and implementation of a natural fire management program require a clear understanding of the goals and objectives for management of the area, an understanding of constraints, and a knowledge of local fire history, vegetation, fuels, and fire behavior. Continual feedback is required to monitor and evaluate the program's success. Details of some of the earliest natural fire management programs in the national parks and wilderness areas of the United States have been well documented (Parsons 1981b; Kilgore 1982). In addition, Fischer (in press) has recently outlined six essential elements in preparing a wilderness fire management plan. The purpose of this paper is to review the important steps in developing and implementing a natural fire management program with special emphasis on examples from Sequoia and Kings Canyon National Parks (SEKI). The discussion is based on a schematic flow chart (fig. 1) designed to guide managers and researchers through a series of important information needs.

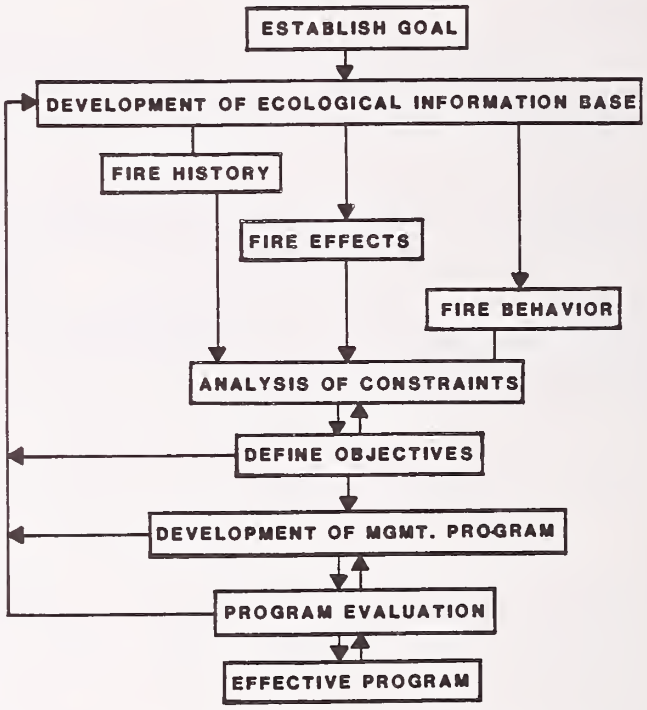

Figure 1.--Flow chart to guide managers and researchers through a series of information needs for natural fire management planning.

ESTABLISHING THE GOAL

The first step in developing a natural fire management program is to clearly establish the management goal for the area. Although this step may seem straightforward, it is not always. For example, although U.S. Department of the Interior, National Park Service, Management Policies (1978) talk about preserving "natural processes" and actually state "natural fires . . . must be permitted to influence the ecosystem if truly natural systems are to be perpetuated," recent debate has concerned whether National Park Service natural fire management should be process or product oriented. Bonnicksen and Stone (1982a) have questioned whether renewing the "fire process" is sufficient or even appropriate. They consider fire to be "a tool that is used to produce some desired state in the condition of an ecosystem." More recently Bonnicksen (1983) has even questioned whether national parks should be managed as wilderness. Instead he proposes they be "a museum for exhibiting outstanding natural features."

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It is essential that the management goal for an area be clearly established. In natural areas this might include perpetuating natural processes or creating or protecting some identified product. The latter might be a "scene" or "vignette" of primitive America (Leopold and others 1963), a given ecosystem or successional stage, or a rare or desired species.

In SEKI the overall management goal is "to allow natural ecological processes to dictate the character" of the environment (Sequoia and Kings Canyon National Parks 1984). In the case of natural fire management this means allowing fire to burn relatively freely, playing as natural a role as possible. Where vegetation or fuel loadings have been sufficiently affected by decades of fire suppression prescribed burning[1] or other manipulative techniques may be used to ameliorate conditions so that natural ignitions may again be permitted. In developed areas, where natural fire cannot be allowed for safety reasons, prescribed fire can be used to mimic natural fire. In the long run, ecosystems should experience the range of fire frequency and intensity with which they evolved. This development of policy to the point of preserving "the forces which cause naturally induced landscape change" has been recently reviewed by McCool (1983).

Unfortunately, even once it has been decided that the goal is to perpetuate natural ecological processes, some questions may remain. In SEKI an unresolved question is whether Indians played a significant role in shaping the local communities and thus should be considered as part of the natural system. If they are considered both significant and natural, managers may be forever simulating Indian ignitions (Lewis 1973), thus injecting considerable subjectivity into the ecological process. If these fires are not considered natural or significant (they were prevalent in the area for only 450 to 850 years before settlement by Euro-Americans) (Vankat 1977) and only fires from lightning ignitions are to be allowed, the results may be increased intervals between fire and thus more intense fires than recent fire history records show (Kilgore and Taylor 1978). Although such conditions may represent those under which local communities evolved, they may not always be acceptable because of safety or other constraints. Managers still must strive to achieve as close an approximation to natural conditions as possible.

DEVELOPING AN ECOLOGICAL INFORMATION BASE

An understanding of the ecosystems of the area, including the history and natural role of fire, the effects of fire suppression, and fire behavior under various conditions, is essential to developing and implementing a natural fire management program. Fire history data must include frequency, seasonality, intensity, location and size, and ignition source for fires as far back as records will permit. In SEKI, preliminary fire history studies have been carried out in the mixed conifer forest (Kilgore and Taylor 1978) and in chaparral and oak woodland (Parsons 1981a). Some information is also available on the effects of fire or fire suppression on vegetation (Harvey and others 1980; Bonnicksen and Stone 1982b), soils (St. John and Rundel 1976), and fuels (Parsons 1978). Additional research is needed in each of these areas, as well as on fire effects on wildlife, water, and air quality. Data on fire behavior (spread rate, flame height, intensity, fire weather, and so on) have been collected as part of the ongoing prescribed burning program. Such information is essential to developing fire prescriptions and predictive models of fire effects and behavior.

ANALYZING CONSTRAINTS

An obstacle to meeting the program goal is the presence of unavoidable constraints. These can include limited funding, special land use classifications, area boundaries, visitor safety, administrative facilities, or any other factor requiring special consideration. Analysis and understanding of such constraints are essential when defining program objectives because they will often require compromising the ecologically ideal situation. In SEKI funding constraints, administrative facilities, and area boundaries have played a significant role in determining specifics of the natural fire management program. It is hoped that agreements with surrounding Forest Service wilderness areas will soon permit lightning ignitions to burn across agency boundaries, removing one of the more serious constraints of allowing fire to play a more natural role in these ecosystems.

DEFINING OBJECTIVES

With an understanding of goals, the ecological information base, and constraints its is possible to develop specific fire management objectives. These objectives should be planned, measurable program results. Fischer (in press) has suggested a number of natural fire management objectives as a function of management goals. The overall objective of the SEKI natural fire management program is to restore fire to its natural role whenever possible by (1) allowing natural and some human-caused fires to burn if they are in prescription and meet predetermined objectives in designated areas, (2) expanding the prescribed burning program to reduce fuels and to alter vegetative composition to a more natural condition where natural fire can be allowed to burn, and (3) suppressing any fire that threatens people and property, or because of other constraints (Bancroft and Partin 1979). More specific objectives, including quantification of fuel reduction or scorch height, are then formulated for individual prescribed burns. As objectives are further defined or revised, new needs for ecological information are often identified.

[1]Editors' note: please refer to the Foreword for comments on prescribed fire terminology.

DEVELOPING A MANAGEMENT PROGRAM

All available ecological information, as well as an understanding of constraints and objectives, must be used in developing an integrated natural fire management program. This includes identifying fire management zones, specific burn units, responsibilities, management guidelines or strategies determining what actions will be taken under what conditions, as well as specific burn prescriptions. Fischer (in press) has given considerable attention to detailing definitions and needs for each of these steps and has presented specific examples as well. The final step in program development is to establish administrative guidelines and procedures for assuring smooth implementation.

In SEKI considerable effort has been given to developing and implementing the natural fire management program. The results have been detailed in the Park's Fire Management Plan (Bancroft and Partin 1979). Three major fire management zones have been established; they are based primarily on the magnitude of changes in natural fire behavior and on effects caused by fire suppression. There are three options in these zones: (1) all natural fires are allowed to burn, (2) natural fires are allowed to burn under restricted conditions while prescribed burning is used to reduce unnatural fuels, or (3) only prescribed burns are allowed, with all other fires being suppressed. Information on vegetation, fuels, and topography is combined with specific objectives to subdivide the lower-elevation zones into prescribed burn units and to develop detailed burn prescriptions and objectives. As additional units, fuelbreaks, or both are burned, the plan calls for allowing natural ignitions to burn under prescribed conditions. The idea is to some day be able to allow most natural ignitions to burn. Even if such a stage can be reached, it is important to recognize that prescribed burns will still be required to simulate ignitions starting outside the park that are suppressed before reaching the boundary. The fire management plan goes into considerable detail in scheduling future prescribed burns, detailing strategies to be followed under varying conditions, and outlining management responsibilities and requirements (Bancroft and Partin 1979). As the program develops, needs for additional basic information will surface, resulting in renewed research efforts.

PROGRAM EVALUATION

A key part of a natural fire management program is having a means to continually evaluate success, as well as to provide feedback to modify program details. This can be achieved through a standardized monitoring program. In addition to monitoring preburn conditions and fire behavior, it is essential to monitor the short- and long-term effects of prescribed burns on fuels, vegetation, soil, wildlife, and other aspects of the environment. Such a monitoring program should be systematically designed to evaluate the ecological effects of varying prescriptions. An understanding of the effects of natural ignitions on ecosystem components is also needed to fully understand the effects of fire on natural systems. In addition to increasing the ecological information base, the monitoring achieves its major purpose, which is to evaluate the success of the fire management program in fulfilling its objectives and ultimately its overall goal. This also allows evaluation of the extent to which prescribed burns may be able to simulate natural ignitions. In SEKI, a systematic fire effects monitoring program has recently been instituted and is reported elsewhere by Ewell and Nichols in this proceedings.

EFFECTIVE PROGRAM

If all these steps are conscientiously followed, an effective natural fire management program should result. Such a program will include a continuously expanding data base that includes information on fire effects, fire behavior, and constraints. Objectives, both general and specific, must be clearly defined and realistic. A systematic evaluation that includes ecological monitoring must be used to assess the extent to which objectives are achieved. It must be recognized that such a program continuously evolves. Details of the program will improve with experience and improved information.

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FIRE MANAGEMENT OPTIONS FOR COASTAL NEW ENGLAND FORESTS: ACADIA NATIONAL PARK AND CAPE COD NATIONAL SEASHORE

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ABSTRACT: Fire is an important component of coastal New England forests. At Acadia National Park, fires are infrequent but may be large. When dry periods of 1 to 2 months coincide with large accumulations of downed spruce, catastrophic fires can result. At Cap Cod National Seashore, fires appear to be more frequent but smaller, although large fires have burned in the region and may occur at Cap Cod. At both parks all but a few fires are human-caused. Present policies of total fire suppression will probably lead to increased fuel loading and greater fire hazard. We recommend implementing prescribed burning programs (with scheduled ignitions) as an effective means of limiting fuel buildup and enhancing diversity in the structure and composition of vegetation.

INTRODUCTION

National Park Service Directive NPS-18 requires all Park Service units that "contain vegetation that can support fire" to develop fire management plans as part of their Resource Management plan (U.S. Department of the Interior 1979). This requirement is based upon the recognition that fire can, depending upon the circumstances and nature of the resource involved, be either destructive or beneficial. Since 1979 most southern and western parks have completed approved fire management plans. Parks in the Northeast have just begun this process because managers have lacked the fundamental knowledge of the natural role of fire in a region where Europeans began to alter natural processes as long as 300 years ago (Stottelmyer 1981).

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We have recently completed basic studies of fire regimes for Acadia National Park in Maine and Cape Cod National Seashore in Massachusetts. In this paper we review the role of fire in those coastal New England forests and discuss fire management problems and options available to resource managers in eastern parks.

SETTING

Acadia National Park and Cape Cod National Seashore are the largest national park units in the Northeast (fig. 1). Acadia National Park was established as Sier de Monts National Monument in 1916. Three years later it was renamed Lafayette National Park and took its present name in 1929. The Park encompasses nearly 35,000 acres (≅14 000 ha)--chiefly on Mount Desert Island but with smaller holdings on Isle au Haut (3,000 acres [≅1 200 ha]) and Schoodic Peninsula (2,000 acres [≅800 ha]). Vegetation and climate are strongly influenced by the proximity of the Atlantic Ocean. Precipitation averages 49 inches (≅1 250 mm) annually, and monthly values range from slightly less than 3 inches (≅75 mm) during the summer to nearly 5 inches (≅130 mm) in November and December.

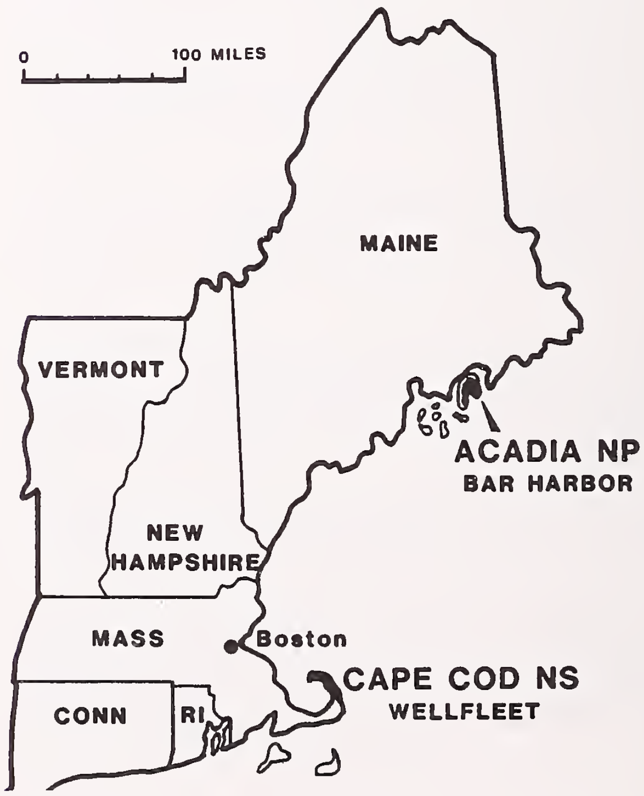

Figure 1.--Map of New England showing the locations of Acadia National Park and Cape Cod National Seashore.

Average winter snowfall is 60 inches (≅1 500 mm). Short but intense periods of drought occur, for example, the lowest monthly precipitation in the 20th century (0.08 inch [≅2 mm]) occurred in October 1947. Conifers, especially red spruce, are the dominant vegetation in Acadia National Park, although aspen and paper birch are common on recently disturbed sites. Soils are variable, but slopes are often steep and depths to bedrock are shallow. Landforms consist of a series of north-south-oriented U-shaped valleys. Cadillac Mountain (elevation 1,530 feet [446 m]) on Mount Desert Island is the tallest peak on North America's eastern coast.

Cape Cod National Seashore was established in 1961 and encompasses 27,000 acres (≅10 900 ha) on the Cape's outer (or lower) arm. Pitch pine and oak forests, dunes, beaches, and salt marshes are the prominent features in a landscape formed from the knob and kettle topography of the Truro, Wellfleet and Eastham outwash plains. Elevations are nowhere higher than 160 feet (≅50 m), and much of the seashore lies within 30 feet (9 m) or so of sea level. As with Acadia National Park, proximity to the sea influences climate and vegetation, but sandy, well-drained soils produce a more xeric environment. Average annual precipitation is 40.5 inches (≅1 030 mm) with the lowest values occurring in summer. The Atlantic's Gulf Stream warms the cape during winter, and snow is less common and persists for shorter periods than at Acadia. The ground is frequently bare during much of the winter. The general lack of winter snow is reflected in the fact that fires have occurred every month for the past 10 years.

FIRE REGIMES

We collected information for each park on historical fire occurrence, fire weather, fuels, and fire-vegetation interactions. Sampling of 20 to 30, 5- to 10-acre (≅2- to 4-ha) stands of homogeneous vegetation in each park provided information on plant species composition, amount and kind of fuels (living and dead, standing and downed), and past fire occurrence (as evidenced by charcoal in the forest floor and fire-scarred trees). Individual fire reports were useful in determining the number, extent, and cause of historical fires despite the incomplete and, in the case of Cape Cod, short period of record. Sedimentary pollen and charcoal studies for Duck Pond on Cape Cod and The Bowl on Mount Desert Island helped trace the role of fire in presettlement forests. The results of these studies are presented in reports published by the U.S. Department of Agriculture, Forest Service, Northeastern State and Private Forestry (Patterson III 1983a, 1983b). They are summarized here to provide a basis for our fire management recommendations.

Fire reports for Acadia National Park are available for 35 of the 49 years between 1937 and 1983. A total of 209 wildland fires burned in or near the Park during these years (table 1). Only five fires have exceeded 10 acres (≅4 ha) (table 2). More than 97 percent were human caused, and of the five recorded lightning fires, none were larger than 0.25 acre (≅0.1 ha). Although lightning has caused as much as 20 percent of all fires in some years in Maine (Fobes 1944), the low number of fires at Acadia National Park is consistent with lightning being less frequent along the coast and almost invariably being accompanied by heavy rain. The great Bar Harbor Fire of October 17-25, 1974, accounted for 98.3 percent of the total acreage burned during the period for which complete records are available. This fire and large fires that burned on Mount Desert in the 19th century (Moore and Taylor 1927) suggest a pattern of infrequent but catastrophically large fires in the conifer forests of the Maine coast. Analysis of fire records and weather patterns for Maine as a whole show that severe fire years occur at about 15-year intervals and that they are more often associated with short 1- to 2-month periods of intense drought than with successive dry years (prolonged drought) (Baron and others 1980).

Table 1.--Summary statistics for recent fires at Acadia National Park and Cape Cod National Seashore

Park	Period of record	Number of fires[1]	Number per year	Area burned[2]		Per year		Number by cause	
				Acres	Hectares	Acres	Hectares	Human	Natural
Acadia	1937-55 1961-68 1975-83	209	6.0	[3]8,905	3 604	371.0	150	204	5
Cape Cod	1974-83	112	11.2	159	64	19.9	8	112	0

[1]Includes some fires reported to have burned on adjacent private property.

[2]Park land only.

[3]Complete fire records including area burned are available for only 28 years. Includes 8,750 acres (≅3 500 ha) burned in the 1947 Bar Harbor Fire.

Table 2.--Acadia National Park and Cape Cod National Seashore fires

	Size class		Number of fires	
	Acres	Hectares	Acadia[1]	Cape Cod
A.	0-0.25	0-0.1	116	76
B.	0.26-9	0.1-3.6	83	34
C.	10-99	3.6-39.6	4	2
G.	≥5,000	≥2 000	1	--
	Total		[2]204	112

[1]Includes some fires that burned on adjacent private land.

[2]Size estimates are unavailable for five fires.

Fires are more frequent at Cape Cod National Seashore, but they appear to be less likely to burn large areas. Between 1974 and 1983, 112 fires affected a total of 159 acres (≅64 ha). To date, fires have been exclusively human caused (table 1). Fires of 10,000 to 20,000 acres (≅4 000 to 8 000 ha) have burned elsewhere on the Cape in the past several decades, however, and the 10-year period that we studied is too short to conclude that catastrophic fires are unlikely at Cape Cod National Seashore.

Fire scars were useful in identifying recorded fires, but they told little about presettlement fires in Acadia National Park and Cape Cod National Seashore. These areas were first settled more than 200 years ago. Our sedimentary studies reveal, however, that fires were an important component of presettlement coastal New England forests. During the past millenium, fires apparently burned Acadia National Park's forest at intervals of perhaps 100 to 200 years but were less severe than the large fires of the 19th and 20th centuries. Given the apparent low incidence of lightning fires, we assume that most ignitions in the presettlement forest were the result of Indian activity. Pollen evidence suggests a postfire successional sequence of gray birch followed by paper birch and finally conifer forests.

At Duck Pond, presettlement fires were, if anything, more frequent and intense than those since presettlement. Oak was more common but so also were mesic forest species like hemlock, beech, and maple. Indians probably burned some areas repeatedly and some areas infrequently.

Most forests at Acadia National Park are even-aged. Nearly one-quarter of the Park is covered by 36-year-old aspen and birch that date from the 1947 fire. Many of these stands have understories of red spruce that regenerated at the same time. Elsewhere most forests are dominated by 100- to 140-year old red spruce. Scattered among these are small stands of red, white, pitch, and jack pine, white cedar, and northern hardwoods. Fir is a less important component of these forests than of inland spruce-fir stands, but white spruce forms pure stands that occupy a narrow (50- to 100-yard [47- to 91- m]) band along the immediate coast (Davis 1966).

Fuel loadings are typically low in most stands at Acadia National Park (table 3), but as spruce

Table 3.--Summary of standing live and dead and downed woody fuel for the Acadia National Park and Cape Cod National Seashore

Park	NFDRS fuel model	Cover types[1]	No. sample stands	Downed woody fuel: 1 hour	10 hour	100 hour	Sound 1,000 hour	Rotten 1,000 hour	Total	Standing fuel: Live >1.4 m	Live ≤1.4 m	Dead >1.4 m	Dead ≤1.4 m	Total
				- - - - - -	- - -	- - -	- - -	- - -	tons per hectare	- - -	- - -	- - -	- - -	- - -
Acadia	G	A1	2	0.73	7.00	9.41	35.60	67.50	120.30	36.7	0.05	20.20	0.29	57.1
	H	A1,A4 A8,A14	11	3.40	2.53	3.33	8.65	7.34	25.30	201.1	.51	19.80	.02	221.5
	K	A1	1	11.64	10.20	13.40	26.80	5.54	67.60	107.0	.53	5.62	.00	113.0
	Q	A1,A23 A25	4	.97	1.05	.71	4.50	2.72	9.97	78.5	2.63	6.59	.51	88.2
	R/E	A9,A11 A12,A14	8	1.99	4.18	3.51	3.23	4.47	17.50	160.5	.36	7.68	.10	168.7
Cape Cod	B	C1,C2	10	.85	1.58	2.53	1.05	.61	6.61	181.1	4.23	18.30	.78	204.5
	H	C1	4	.71	1.00	2.16	1.51	.97	6.35	165.8	1.00	10.60	.24	177.7
	L	C3,C9	3	.12	.12	.00	.00	.00	.24	23.3	.32	.17	.10	23.8
	R/E	C6	1	.97	2.87	1.70	.00	6.32	11.90	184.3	2.82	21.40	1.07	209.6

[1]Cover type codes:

A1	Spruce-fir	A12	Red oak	C1	Pitch pine	C6	Beech
A4	Cedar forest	A14	Mixed hardwood-conifer	C2	Black oak/white oak	C9	Mixed grass
A8	Mixed conifers	A23	Pitch pine	C3	Bearberry		
A9	Birch-aspen forest	A25	Jack pine				
A11	Northern hardwoods						

stands mature they become increasingly susceptible to wind damage. The Fuel Model G (Deeming and others 1977) stands that result from blowdowns pose serious fire hazards. Logging and agriculture abandonment reached their peak in the late 19th century on Mount Desert Island, and many second-growth spruce stands are now reaching maturity. This is true also for Isle au Haut, where an 1879 fire swept the entire island. We estimate that as much as 70 percent of the Park is occupied by maturing spruce forests and that these stands will present significant fire management problems for at least the next half century.

The pitch pine and oak forests of Cape Cod National Seashore are the result of large fires and agricultural land abandonment that continued through the early decades of this century. Landscape diversity is lower than at Acadia National Park, and the homogeneous forests have a dense understory of ericaceous shrubs. The highly flammable huckleberry is an important component of the vegetation, and although downed fuel loadings are low, fire is a persistent problem in Seashore forests. Beach grass on the dunes and dense stands of common reed grass pose fire hazards that are unique to the low-lying coastal vegetation of the Seashore.

Virtually all of the stands that we examined at Acadia National Park and Cape Cod National Seashore had charcoal in the forest floor, and there is little doubt that fire played an important role in establishing the present vegetation of both parks.

FIRE MANAGEMENT RECOMMENDATIONS

In the absence of an approved fire management plan, parks are required to suppress all fires whether natural or human caused. Resource managers at both Acadia National Park and Cape Cod National Seashore are now developing fire management plans based upon data presented in our reports. Options that can be considered include suppression of all fires, suppression of human-caused fires with prescribed natural fire (unscheduled ignitions), and scheduled (prescribed) ignitions for specific management objectives. In this section we discuss the advantages and disadvantages of each option.

Continued Suppression Of All Fires

Public education programs and complete suppression of all wildland fires are the primary fire management tools of resource managers in New England. We know of only one place (at Otis Air National Guard Base on Cape Cod) where large-scale prescribed burning (with scheduled ignitions) is being considered as a management tool in coastal New England forests.

Although most rangers at Acadia National Park and Cape Cod National Seashore have experience with prescribed burning in the West and South, they are reluctant to consider it in New England, in part because they lack fundamental information on fire behavior in these forests and because it is believed that widespread public sentiment would oppose scheduled ignitions. Their concerns are well founded. Many residents of Bar Harbor hold vivid memories of the 1947 fire, which caused more than $12 million in damage. Most believe that any wildland fire, whether accidental or a result of scheduled ignition, has the potential to create a conflagration of similar magnitude. In Massachusetts, strict air quality and open burning regulations require those who would conduct prescribed burns to pursue a lengthy approval process. Interestingly, however, burning for agricultural purposes is a common practice in both Maine and Massachusetts.

Despite vigorous fire prevention programs, wildfires occur during most years at both Acadia and Cape Cod. Virtually all of these fires are human caused; and as visitor use and local populations grow (the two parks combined had more than 8 million visitor-use days in 1982), it is likely that ignitions will continue to be a problem. Between 10 and 20 percent of all fires are believed to be of incendiary origin, and the prevention of these types of fires is especially difficult.

Given that ignitions are likely to continue at least at present levels, a policy of complete suppression could have serious consequences, especially at Acadia National Park where we predict fuel loadings will increase dramatically in the next several decades. Blowdowns produce large volumes of highly flammable fuel that may persist for 20 years or more (Spaulding and Hansborough 1944). In Maine, the interval between periods of drought seems to be less than the time required for downed red spruce branches to decay. Park managers will be fortunate, indeed, if they can avoid a major conflagration during the next 25 to 50 years.

The consequences of a complete suppression policy are less clear at Cape Cod National Seashore. Large amounts of fuel do not appear to accumulate, but suppression leads to the invasion of pine stands by shrubs that provide vertical continuity to forest fuels and increase the risk of surface fires expanding to crown fires that are difficult to control.

Both parks have environmental resources that could be threatened by a policy of complete suppression. Although small, jack pine and mixed red and white pine stands at Acadia National Park and heath communities at Cape Cod National Seashore represent unique vegetation types that may be fire dependent. More study of these communities is needed, however, as other factors (for example, grazing in the Cape Cod heathlands) may also be important in their maintenance. Clearly hazardous fuel accumulations are the primary concern in both parks. Although cutting and herbicide use, as well as prescribed burning, can be effective methods for managing fuels, the former practices can be costly and may be in conflict with National Park Service policy. It is for these reasons that we considered prescribed burning as a fire management tool.

Prescribed Natural Fire (Unscheduled Ignitions)

Although it has been effectively employed in larger parks that are far removed from population centers, we see little likelihood that prescribed natural fire (unscheduled ignition) will ever be a viable fire management option for either Cape Cod National Seashore or Acadia National Park. Lightning fires rarely occur, and when they do they are usually extinguished by heavy rain. Perhaps more important, the parks are not configured in a way that allows safe application of prescribed natural (unscheduled ignitions) fire. Neither park has an official wilderness designation; both have high, often widely despersed, visitor use; and both are relatively small parks with complex boundaries characterized by extensive inholdings and adjacent private property. At Cape Cod National Seashore, for example, 1,200 acres (485 ha) of private land is divided among 539 tracts, and at Acadia National Park numerous small towns lie within Park boundaries or abut them directly. We know of nowhere in the Northeast where prescribed natural (with unscheduled ignitions) fire is being considered as a management option, and we doubt that it will be in the foreseeable future.

Scheduled Ignitions

Although they are not currently being employed, prescribed burns with scheduled ignitions conducted under clearly defined and carefully monitored weather and fuel conditions could be a useful management tool at both parks. New England coastal vegetation has been influenced by fires burning in presettlement and postsettlement time. Humans are currently the primary ignition source and that has probably been the case for at least the past several hundred years. Fire intensity and frequency has probably varied with changing weather and fuel conditions, human population density, and cultural practices; and there would seem to be little value in arguing whether these fires were, or are, "natural." Lightning fires are rare in coastal New England, but there is strong evidence that fires of undetermined origin have burned at more or less regular intervals for at least the past 10,000 years (Winkler 1982; O'Keefe and Patterson 1980).

We recommend that for both parks a major resource management goal be to provide greater diversity in the structure and composition of the vegetation. Past land use practices (including complete fire suppression in recent years) have uniformly distributed fuels; this fosters conditions conducive to the outbreak of large destructive fires. Prescribed burning with scheduled ignitions could be used to reduce fuel loadings in those areas where unscheduled ignitions are most likely to result in control problems (for example, on xeric south- west-facing slopes, in recent blowdowns, or where visitor use is high). At the same time, increased fire protection could be afforded those areas that are identified as likely to succeed to less flammable vegetation (for example, northern hardwoods). Both parks have extensive networks of roads and trails that could be used as firebreaks.

A prescribed burning (with scheduled ignitions) program in the parks must be compatible with local fire protection efforts and abide by State and local regulations regarding open burning. In Massachusetts, local volunteer fire departments are the mainstay of fire protection. The fire chief in the town in which open burning is to be conducted is responsible for issuing burning permits, and except under special circumstances these are available only from January 15 to April 30. Although sentiment varies from one town to the next, we have found local fire departments to be supportive of our efforts to develop prescribed burning programs on Nantucket Island off Cape Cod and on the Quabbin Reservoir in central Massachusetts. The Massachusetts Department of Environmental Quality Engineering has been willing to waive air quality regulations when we have demonstrated that prescribed burning is the safest and most effective means of attaining specific management objectives. The Commonwealth's chief fire warden has also supported our efforts.

As in other areas of the country, an active public education program is necessary to inform park visitors of the need for fuel management programs and the value of prescribed burning with scheduled ignitions as a means to reduce fire hazard over the long term. The Park Service is well equipped to conduct such a program, which might have the added benefit of heightening awareness of the need for fire prevention. On Nantucket, we have found local residents to be eager to learn about our efforts to use fire to maintain heath communities. Local journalists have also supported our efforts. Prescribed burning with scheduled ignitions is somewhat of an innovation in New England today, but most people realize that it was a common practice in the past.

Fire is inevitable in the coastal vegetation of Acadia National Park and Cape Cod National Seashore; fire has occurred in the past and will occur in the future. Resource managers can, through their fire management practices, determine to a large extent whether these fires will burn as unplanned and potentially destructive wildfires or as carefully controlled and largely beneficial prescribed burns.

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FIRE--AN OLYMPIC EVENT

Denison M. Rauw

ABSTRACT: The slide-tape program, "Fire--An Olympic Event," addresses the natural role of fire in Olympic National Park and the changes in fire management planning in national park lands and other federal lands that are managed for their wilderness values. In their interviews, park managers, local "pioneer" residents, and park biologists gave their perspectives on the role that fires play in a national park ecosystem. The 28-minute program was funded by the Cooperative Park Studies Unit at the University of Washington, College of Forest Resources, Seattle, Wash., and produced at the University of Idaho, Department of Wildland Recreation Resources, Moscow, Idaho.

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FIRE HISTORY AND ECOLOGY OF THE NORTH COAST RANGE PRESERVE

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For the past 20 years the 8,000-acre (3 238-ha) Coast Range Preserve has been managed for three major uses: (1) research by government agencies, (2) educational field trips by schools and history groups, and (3) nature study and appreciation by the public. The Preserve is cooperatively owned and managed by the Nature Conservancy and the Bureau of Land Management. A Natural History Association provides numerous materials and activities.

The goal of this investigation is to (1) prepare a fire history of the Douglas-fir (*Pseudotsuga menziesii*) mixed evergreen forests on the Northern California Coast Range Preserve (NCCRP), (2) determine how the occurrence of fire (and its return) influenced the distribution of Douglas-fir and mixed evergreen forests in the Elder Creek drainage, and (3) determine the effect of fire on the vegetation of the Barnwell Creek drainage before logging. Additionally, this report identifies the prescribed burning conditions and frequency required to mimic nature. The information provided by this investigation can also be used as background material for dialogs with fire protection agencies concerning fire suppression strategies and fire management on the Preserve.

SETTING

The area investigated is on the free-flowing South Fork of the Eel River, which is on the eastern edge of the North Coast Redwood Range. One of the two areas studied along the Conger Jeep Trail is in the Elder Creek drainage, which is 6.5 mi^2 (16.8 km^2). Elder Creek is one of 57 national hydrologic benchmark stations established by the U.S. Department of the Interior, Geologic Survey. It was so established because it is virtually undisturbed by logging and road building. This watershed was also the first Natural History Landmark declared by the U.S. Department of the Interior. The other area studied was in the Barnwell Creek drainage located west of the South Fork of the Eel River and was logged in 1950.

The weather of the Preserve is a mediterranean type. It is in an area with one of the highest rainfalls in California: 84.9 inches (2.156 meters). The intensity of rainfall is especially high. The fire season extends from July to September, which is relatively short for California wildlands. Lightning occurs infrequently. The topography of Elder Creek and Barnwell Creek is oriented east-west with gentle to steep slopes that are highly dissected. Cold air drainage is pronounced in the Preserve. Vegetation of the Preserve includes chaparral, meadows, and knobcone pine (*Pinus attenuata*), mixed evergreen, and Douglas-fir forests.

METHODOLOGY

The investigation focused primarily on fire history information afforded by the study of fire-scarred trees. Studies such as this can yield information such as average, minimum, and maximum fire-free intervals and the intensity and extent of fires. This information is useful to explain the role of fire in the stand structure, natural regeneration, and nutrient cycling. Local fire history data can provide a scientific basis for prescribed fire at specific intervals and can be extrapolated to areas with similar vegetation and topography.

Following Arno's and Sneck's methodology (1977), we recorded habitat type and stand composition field data, in addition to stand structure and age, for each vegetation type and significant stage of succession. The five sample sites chosen were (1) Douglas-fir in a canyon bottom, (2) Douglas-fir on a ridge top, (3) Douglas-fir midslope, (4) tanoak (*Lithocarpus densiflorus*) with regeneration, and (5) tanoak stands that are nonreproducing. Stratifying vegetation types and successional stages makes it easier to extrapolate results to similar conditions. Data collected included the species present and cover density of each species. Subjective notes concerning the state and dynamics of the vegetation were also recorded as field observations. Seral coniferous trees were cored and aged; diameters were recorded for all trees by 2-inch (5-cm) classes and by species.

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Fire-scarred trees were located and recorded along 50- to 100-ft-wide (15- to 30-m-wide) reconnaissance transects leading through representative aspects and elevations. Trees with the highest number of well-defined scars were sampled by taking a wedge from each tree. We used a variety of criteria to select trees. We preferred trees with a clear sequence of scars or with numerous scars and older trees, because we were interested in the periodicity of fires before settlers arrived (before the 1880's). We also selected all stumps with more than one apparent fire scar. The lean of the tree also affected selection, because many trees that would otherwise bear good scar sequences leaned on the side from which the wedge would be taken. We counted rings on the sample wedges, noting the number of years between fires, the total number of rings present or the number of rings to the pith, and the intensity of each fire when evidence of such was present.

From the stand structure analysis and ring counts we developed a master fire chronology that correlated regeneration of seral trees with recorded fire dates. The subsequent interpretation of fire's effects on these vegetation communities was based on the chronology, literature, field observations, and photographs.

Investigating fire histories through the use of fire-scarred trees has its limitations in interpretation and application. Human activities change the fire frequency and fuel complex. It is also difficult to obtain clear old scarring dates because of rot, subsequent fires that burn off old scars (this factor was especially important), insect activity, and the limited number of older trees available because of tree mortality. If fire chronologies are not cross-dated using sophisticated dendrochronology techniques, the data can be suspect. Unfortunately, this procedure requires much time and therefore was not undertaken in this study.

Fire scars represent a conservative history of past fires for a variety of reasons. Fires must be intense enough to scar the cambium tissue of the tree. Fires vary in intensity and may not scar all trees. Further, subsequent fires often burn previous scars, making the interval between fires appear longer than it actually is. Trees with scars seem to be more susceptible to scarring during subsequent fires.

DESCRIPTION OF VEGETATION

The following sections describe the vegetational species and the successional routes in the Douglas-fir and mixed evergreen forests (with and without fire). They also include information about pure Douglas-fir stands of old growth.

Conger Jeep Trail

Closed stands and the broad-leaf scherophyllous nature of the dominant species typify the mixed evergreen forests on the Conger Jeep Trail, but may also contain a few conifers. Characteristic dominants include madrone (*Arbutus menziesii*), tanoak, canyon oak (*Quercus chrysolepis*), and Douglas-fir. The vegetation consists of well-developed pure stands of Douglas-fir, tanoak, and madrone as well as mixtures. Sawyer and others (1977) report various stages of a single forest type; the existence of different stages is due to dynamic, competitive plant interactions that relate to the history of disturbances. In the north coastal mountains, Douglas-fir/hardwood forests form a complicated mosaic of early and late successional communities, resulting from a long history of fire, grazing, and logging. Johnson (1979) reports that the only thing that distinguishes this vegetation type from Douglas-fir forests is the Douglas-fir has not yet attained dominance, although it ultimately will. The mixed evergreen forests on the Conger Jeep Trail exist at higher and at more southern exposures than Douglas-fir forests. The mixed evergreen forest has replaced much of the chaparral that existed during that period when the study area maintained fires set by settlers and Indians.

The dynamics of the mixed evergreen forest are characterized by a modal community in which succession advances for a long time until disturbance returns the vegetation to earlier stages. The tree layer of the mature modal community in mixed evergreen forests consists of Douglas-fir and tanoak. The canopy on the Coast Range Preserve has three heights. Douglas-fir forms an irregular upper tier as high as 215 ft (65 m). Tanoak forms a more continuous lower canopy at heights to 115 ft (35 m). Madrone, canyon oak, and chinquapin (*Castanopsis sempervirens*) are lesser components in the second level of the canopy. The lowest layer of the canopy is almost shrubby, often at heights of 20 ft (6 m). This third layer is composed of California bay (*Umbellurlaria californica*), tanoak, canyon oak, hazelnut (*Corylus cornuta*), and dogwood (*Cornus nuttalli*). Seedlings of both tanoak and Douglas-fir are present in most stands. Forbs common in this community are *Gaultheria shallon*, *Berberis nervosa*, *Rosa gymnocarpa*, and poison oak (*Toxicodendron diversilobum*).

Stands of pure Douglas-fir occur on south-facing slopes in even-aged stands generated by fire where chaparral and Douglas-fir germinated and grew together. Normally Douglas-fir overtops the chaparral. The chaparral, being short lived and requiring more light, will die out leaving pure Douglas-fir stands. The hypothesis that allelopathy is inhibiting germination of hardwood seeds, but not conifer seeds, would explain the continued lack of tanoak even after the brush died, for allelopathy is broken only by fire even in areas of thick duff buildup. This seral habitat completely overlays the area of the modal phase forest. On similar sites the composition of more mature uneven-aged

stands closely resembles that of the modal community. In other areas of comparable habit, tanoak is dominant in early successional stages. Douglas-fir invades as tanoak matures to form a mature forest character of the modal community (Sawyer and others 1977).

After burning or logging, very dense, nearly pure, even-aged stands of tanoak or Douglas-fir can form. In other situations a mixture results. If a severe fire killed aerial portions of the mature modal Douglas-fir/hardwood community described above, tanoak would be completely dominant in the regeneration. When tanoak matures and senesces, Douglas-fir gradually invades the opening stand. Seedlings of both species then grow slowly, taking advantage of canopy openings produced by the death of local trees. Invading Douglas-fir seedlings will outgrow tanoak seedlings under reduced light. Because of its long life, Douglas-fir will eventually dominate; tanoak will maintain itself in the lower canopy.

In a burn of moderate intensity an adequate seed source of Douglas-fir generally remains in the area, so that both tanoak and Douglas-fir regenerate. Tanoak sprouts first surpass Douglas-fir seedlings in height and dominate, but Douglas-fir slowly increases in height until it dominates the tanoak.

In other situations mixed stands may be relatively open, allowing both Douglas-fir and tanoak to continually regenerate. All successional sequences, though, lead to the same mixed composition. Examples of the mature modal community are rare because of frequent fire. Most forests along the Conger Jeep Trail now consist of even-aged stands of Douglas-fir or tanoak or of two to three age classes that result from several disturbances (Sawyer and others 1977).

Although fire plays an important role in determining the distribution of Douglas-fir and hardwoods and, within hardwoods, the distribution of madrone and tanoak, soils are also an important determining factor. Cooper and Krohn (1968) suggested the order of dominance in hardwoods may be reversed by soil type. On Melborne soils tanoak dominates madrone; whereas on Hugo soils madrone is more common than tanoak.

Old-growth Douglas-fir stands.--Old-growth Douglas-fir stands are especially important in the management of the Coast Range Preserve, so this discussion focuses on forests that are advanced in successional stage. Such areas exist mostly on canyon bottoms and river benches and resemble somewhat the old-growth Douglas-fir forests of the Pacific Northwest. The forests of lower elevations of the Klamath and North Coastal Mountains are not southern extensions of Pacific Northwest coniferous forest in more favorable habitats, however; instead they are part of the vegetation mosaic of mixed evergreen/ Douglas-fir-hardwood forests. In the Pacific Northwest forests, Douglas-fir is an early successional species; here it plays a very different role as it is also a major part of the climax vegetation (Sawyer and others 1977).

Douglas-fir is purported to be the ultimate climax forest type for this terrain and climate. One-half of the Preserve is classified as Douglas-fir, which grows with coast redwood (*Sequoia sempervirens*) in watered flats and extends upslope and becomes dominant in well-developed stands. Douglas-fir grades into tanoak and madrone on uphill margins (Johnson 1979).

The diversity of the tree structure begins early; 90- to 130-year-old stands show a great range of tree sizes and multilayered canopy. Tree crowns begin 65 to 130 ft (20 to 40 m) above ground. At 175 to 250 years of age, forests begin to assume old-growth characteristics.

In areas where redwood could invade, Douglas-fir should be considered seral; redwood would be the ultimate climax species. Most stands tend to retain a significant component of long-lived Douglas-fir in the dominant tree canopy and will continue to do so for several centuries.

Large masses of logs on the ground are an important characteristic of old-growth stands; 38 to 85 tons/acre (15.8 to 35.4 tonnes/ha) from downed logs are common, but weights vary widely. The fuel loading on the Coast Range Preserve is rarely as high as 60 tons/acre (25 tonnes/ha) but is consistently heavier downslope. In old growth, carbon and nutrient cycling is a closed cycle, detritus-based system. Detritus decomposes slowly through heterotrophic organisms, fungi, bacteria, and invertebrates. Logs also decompose slowly; a 30-inch (76-cm) log requires 480 to 580 years to decay 90 percent. Although the larger number and mass of snags and rotten logs are cited as important characteristics of streams in old-growth Douglas-fir stands, Elder Creek, a pristine water drainage system in an old-growth Douglas-fir stand, was obviously clear of these logs and snags.

Barnwell Creek Drainage

The climax vegetation of the Barnwell Creek drainage consists of redwood, Douglas-fir, and tanoak; Zinke (1977) classified it as redwood forest. When this type is logged, all species are capable of sprouting except Douglas-fir, which will seed in soon after, creating an even mixture of all species. On a stand in the southeast quarter of Branscomb quadrangle, sprouting hardwoods dominated the site within 4 to 8 years, but in 15 more years fairly tall stands of hardwoods and conifers will result. By 70 to 85 years after disturbance, redwood and Douglas-fir will overtop the hardwoods, and the original community will return (Zinke 1977). Coast redwood forests retain large dominant specimens of Douglas-fir in true climax conditions (Franklin and Dyrness 1973). Figure 1 further details successional routes of this vegetation type.

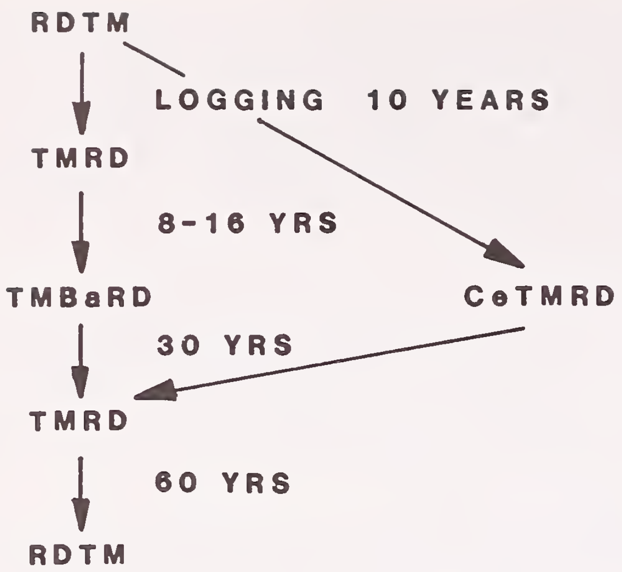

Figure 1.--Seral stages in the redwood-Douglas-fir-tanoak-madrone forest after harvest disturbance in an area along the South Fork of the Ten Mile River, Mendicino, Calif., latitude 39° 33'N (adapted from Zinke 1977). R = redwood; D = Douglas-fir; T = tanoak; M = madrone; Ce = ceanothus ecanis; Ba = bare ground.

FIRE HISTORY

Conger Jeep Trail

Rings were counted on 11 samples from tanoak trees and madrone stumps. Stumps were assumed to have been cut in 1958, the year the trail was built. Three samples were taken in vegetation classified as Douglas-fir forest type. Two samples were taken in pure tanoak stands classified as mixed evergreen. Other samples in various stages of succession were taken within the mixed evergreen forest type.

The 11 samples yielded evidence of 8 fires from 33 scars over a 103-year period, or a fire frequency of 12.9 years. Only fires that scarred two trees were considered in determining fire frequency. These fires included one fire from 1925 to present (a fire frequency of at least 58 years) and seven fires from 1880 to 1925 (a fire frequency of 6.4 years). These two periods correspond to the settlement time and the era of protection. Unfortunately, no two trees yielded scars dating to a time that would indicate whether Indians burned in the area.

From 1927 to 1983, the maximum interval between fires was 46 years. The minimum interval between fires (4 years) occurred between 1880 and 1884. Of the 11 fires sampled, the one that scarred the most trees (5) occurred in 1904.

Two of the three trees sampled in the Douglas-fir vegetation type indicated the most recent fire occurred in 1904, or 79 years previously. In contrast, the majority of trees sampled in the tanoak vegetation type (in a variety of successional stages) had experienced more recent fires, from 20 to 64 years previously.

Of the 58 fire scars on the samples brought back for analysis, fire intensity was indicated as moderate in 11.8 percent, light in 11.8 percent, and intense in 45.6 percent; 30.8 percent of the fire scars were not clear enough to interpret. Intensity was estimated by the depth of the scar and percent of cambium exposed. Future investigations should also use the decrease in ring growth as a criterion.

Barnwell Creek

Ten stumps were sampled in the Barnwell Creek drainage along the Guimelli Jeep Trail in the Douglas-fir vegetation type. These 10 stumps contained 49 scars resulting from at least 12 fires between 1819 and 1950. The fire history of the area is characterized by frequent burning. The average fire frequency is 12.3 years. For this analysis the time period was divided into three eras. From 1827 to 1885, the presettlement era, five fires scarred trees, resulting in a 11.3-year fire frequency. From 1885 to 1925, the homesteading era, five additional fires scarred trees, resulting in an 8-year fire frequency. From 1925 to the time of logging in 1950, two fires scarred trees, indicating a 13.5-year fire frequency.

The stumps were fairly rotten along the cambium; and although every effort was taken to preserve and enhance indications of rings, fire dating under these conditions provides estimates not absolute dates. There may be, in fact, fewer fires than are shown on the master fire chronology because more drastic shifting of time lines make more dates of fires match. Whether the fire frequency was 12.3 years or 15.3 years (resulting from 8 rather than 12 fires), the effects of the fires do not change. Recorded on one tree were 19 fires from 1664 to 1950 (a fire frequency of 18.4 years); fires before 1827 were not included in the calculations of fire frequency for the entire area because no two trees recorded the same fire.

The minimum interval between fires in the Barnwell Creek drainage occurred between 1923 and 1927. The maximum interval was 22 years, between 1827 and 1849. The fire that scarred the most trees (5 of the 10 stumps sampled) occurred in 1928.

CONCLUSIONS

In both the Elder Creek and Barnwell Creek drainages the fire frequency data indicate settlers burned repeatedly and confirm personal accounts and hypotheses to that effect. Where samples have up to 400 clear rings, fire frequency does not decline with time, which indicates Indians also practiced burning. One stump, with 19 fire scars dating back to 1644, supports the contention that Indians burned as far back as 1644. Eight fire scars between 1833 and 1664 indicated a fire interval of 27 years. This interval is an extremely conservative estimate because many more scars were probably burned off in any of the 11 fires after 1833. Frequent burning would explain the

patchiness of the landscape, the presence of old, pure stands, and open quality (having little understory) of many mixed stands, in addition to the presence of distinct age classes.

It is impossible to determine the natural fire frequency (not including Indian manipulations) from fire scars because these trees do not date back 5,000 years, which is the approximate length of Indian occupation. It is possible to estimate the natural frequency of fire if the frequency of lightning strikes, the rate of fuel buildup, and length of fire season are known. The fire-free interval between lightning-caused fires in the Preserve may be long, but prehistoric fires burned for months and consumed vast areas (even much larger areas than would burn in times of Indian burning).

The fire-free interval generally lengthens the farther back in time one investigates because the previous fire scars are likely to have been burned off by subsequent fires. Although the Barnwell Creek drainage did not follow this pattern, most other places, like the Conger Jeep Trail area, do. The reduced number of older trees in the study areas also results in longer fire frequencies. Almost all the redwood stumps were at least 350 years old.

Information concerning fire history can be supplemented by using samples of dying or fallen trees. Information about the year of death and the vegetation present should be noted so relationships between these and other factors can be established. The health of live trees sampled in this investigation should be monitored to determine the impact of this technique on individual trees.

Although most of the trees had clear sequences of five to six fire scars during the reconnaissance transect, several of the samples contained so much rot that previously clear evidence of scars fell off during sampling. In some cases the remaining sound wood had indications of fire scars; however, fire scars were surely "lost" due to rot. One of the benefits of performing a fire history of this nature is that the information collected will remain long after the evidence on standing trees has decayed.

Vegetation Classification

The vegetation of the Conger Jeep Trail was previously classified as Douglas-fir and mixed evergreen forests; however, the vegetation is really one type, mixed evergreen forest, in varying stages of succession. Several sites, which were both pure tanoak stands and mixed forests of Douglas-fir, tanoak, and chinquapin, were tended with fire. The discontinuity of the tanoak stands and the open, grown nature of the mature trees of all species indicate that several light fires have occurred in the area. These sites were on northern aspects. If they were on southern aspects, one would expect to find open grown trees because they grew up through chaparral in low density. In areas where fire was not frequent, tanoak stands would be expected to also contain Douglas-fir seedlings.

Fire Management Considerations

Fire significantly influenced the distribution of species within the mixed evergreen forest type, especially the distribution of Douglas-fir. The occurrence of fire explains the fact that mature tanoak specimens with an open, grown character occur on both "tanoak" stand structure analysis plots. All trees in this vegetation type had fire scars and had survived at least one fire, but because fewer fires have occurred in the area since 1925 this more dense group of trees has not been thinned by repeated fires. The stand is now beginning to break up, and Douglas-fir is expected to enter the openings created by tanoak mortality.

Trees sampled in areas classified as Douglas-fir had fewer scars (although it is possible the evidence of fires fell off the samples). Conditions in the areas with frequent fires do not permit Douglas-fir seedlings to become established. For example, two samples taken from pure nonreproducing tanoak stands had six fire scars. Stands with a higher proportion of tanoak were in areas of more recent fires. Two of three samples taken in vegetation classified as Douglas-fir had had the most recent fires (79 and 84 years previously). In contrast, three of four samples that showed evidence of the most recent fire (46 years previously) were in areas with a tanoak overstory and were classified as mixed evergreen forest type.

Douglas-fir and madrone appear on more moist sites, lower on the slope (closer to a river influence and in areas of more runoff), in draws, and on deep soils (with more water holding capacity, in general), in contrast to areas with only tanoak in the overstory, or in areas with a higher proportion of tanoak in the overstory. Thus the extremes range from the Douglas-fir-canyon bottom plot, with no tanoak in the plot, to the tanoak-nonreproducing plot where Douglas-fir does not appear on the site. But in the absence of fire, Douglas-fir will eventually spread up the entire north-facing slope of the Elder Creek drainage. The vertical spread of Douglas-fir upslope will be much slower than the horizontal spread or spread into canyons because of reduced soil depth, less river influence, seed dispersal mechanisms, and reduced runoff.

In mature tanoak stands light fires, regardless of frequency, thin stands and enhance acorn production. Light fires prevent Douglas-fir seedlings, and maintain a pure tanoak forest of low stocking. Repeated fires of low intensity promote the open grown appearance of many sites visited where tanoaks possessed low, thick branches and otherwise displayed an open grown habit.

The role of fire under natural conditions does not appear to be gentle on the Coast Range Preserve; it is likely to be stand replacing. The longer interval between fires would allow a heavier build-up of fuels and vegetation to progress further toward a climax stage in larger areas. When a fire did occur, the burned area would be much larger than present and the intensity would

be greater. Stands in this area were typically established in blocks of hundreds of acres. Boundaries occurred along topographic features, ridges, and streams. Boundaries were feathered, making large areas of mixed stands (with residual old growth, scattered through young-growth Douglas-fir). Fires often skipped large patches of trees, especially on lower slopes, stream bottoms, and areas protected through natural barriers (Franklin and others 1981). In addition, large areas burned under less intense conditions. This scenario is substantiated by the larger and more intense fires that have resulted after allowing fuels to build up for only 70 years in California. The pattern of vegetation would be less uniform than that created by the light burning over the past 5,000 years, as noted by Lewis (1974).

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EVERGLADES NATIONAL PARK: FIRE

Regina M. Rochefort and Robert F. Doren

ABSTRACT: Everglades National Park is located at the southern tip of Florida and encompasses 1.5 million acres (0.6 million ha). It includes approximately 990,000 acres (≅400 000 ha) of terrestrial resources and 510,000 acres (≅207 000 ha) of marine resources. The subtropical climate is characterized by dry winters and wet summers, average minimum/maximum temperatures of 60°/84° F (16°/29° C), and an average rainfall of 54 inches (≅1 370 mm). Terrestrial resources are addressed in the Everglades Fire Management Plan as three reasonably distinct units: mangroves, prairies, and pinelands. Each unit has unique fire prescription parameters and management concerns.

The mangrove unit encompasses 512,000 acres (≅207 000 ha) along the western and southern coasts and is comprised of three subunits. Mangrove (*Rhizophora*) swamps cover the largest area in this unit and are infrequently affected by fire. Though summer lightning strikes do occur in this zone, fine fuels are sparse, and most tree mortality is due to electrical conductance. Coastal prairies occur on well-drained marl soils. Before the park was established, these prairies may have been enlarged and maintained by Indian or European burning or both. Estuarine marshes cover approximately 75,000 acres (≅30 000 ha) in this unit and are often burned by lightning strikes. Management concerns and research needs in this unit include endangered Cape Sable Sparrow populations, feasibility of using fire to contain or control exotic plant populations, determination of past fire history, and fire impacts on wildlife.

The prairie unit comprises 356,811 acres (≅144 000 ha) in three subunits ranging from 1 to 3 ft (≅0.3 to 0.9 m) elevation. Shark River Slough extends through the center of the unit and is dominated by sawgrass (*Cladium jamaicense*) strands on deep organic soil. Spike-rush (*Eleocharis*) communities and tropical hammocks are interspersed through the area on marl soils and rock outcroppings. High and low prairies surround the slough and are dominated by varying densities of muhly grass (*Muhlenbergia filipes*) and other grasses and sedges. This unit has been greatly affected by changing hydrologic patterns, exotic plant incursions, and adjacent land uses. Some of these impacts are now being monitored and assessed, but even more research is needed in this area. Prairies also include much of the Cape Sable Sparrow habitat, and prescription parameters address this issue.

Everglades pinelands covering approximately 20,000 acres (≅8 000 ha) are the last remnant of once extensive (181,660 acres [≅73 500 ha]) Miami Rock ridge pinelands. The pinelands are composed of South Florida slash pine (*Pinus elliottii* var. *densa*), 61 taxa of tropical and temperate shrubs, and at least 191 species of herbs and grasses. Fire is an integral component of the pineland ecosystem, though fire history of the area is far from definitive. Accounts from early explorers (ca. A.D. 1500) document Indian burning, but tree ring analysis for South Florida has not been perfected, making it difficult to estimate past fire frequencies. Most pineland prescribed burns are scheduled in the wet season to approximate the timing of lightning strike (natural) fires. Some areas with special considerations, such as exotic incursions and dense hardwood understories, are burned in the dry season.

Fire management in Everglades spans three decades and several ecotypes. Through research projects and field observations, prescription parameters have been relatively well defined as they pertain to fire behavior; however, in keeping with our overall goal of reproducing the long-term effects of fire to perpetuate the ecosystem as naturally as possible, we must monitor those effects directly. Research oriented toward documenting and understanding fire's effects on the system is a vital part of our fire management program.

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FIRE HISTORY IN SUBALPINE FORESTS OF YELLOWSTONE NATIONAL PARK

William H. Romme and Dennis H. Knight

The fire history of a 18,000-acre (7 300-ha) subalpine watershed in west-central Yellowstone National Park was determined through fire scar analysis. Evidence indicated that seven fires encompassing more than 10 acres (4 ha) and eight smaller fires had occurred since 1600. The larger fires were destructive, stand-replacing fires; and most of the upland forest area, dominated by lodgepole pine, subalpine fir, and Engelmann spruce, was burned by large fires in the 1700's. Since 1800, fires have been small and have occurred at long intervals, apparently because of changes in the vegetation structure and fuel complex following the extensive fires of the 1700's--not because of human fire suppression. Sampling along a chronosequence of stands indicated that living and dead woody fuels capable of supporting a second intense fire do not develop until a stand is 300 to 400 years old. Ignitions in younger stands usually produce low-intensity fires that extinguish naturally before burning more than a few hectares.

Using fire history data and observations of successional patterns in this area, the sequence of vegetation mosaics during the past 240 years was reconstructed for the watershed. Late successional forests (300+ years old) apparently predominated in the early 1700's, but these were largely replaced by early successional stages after the great fires of that century. Because of continued successional change and a paucity of fires, middle successional forests dominated the watershed by the mid-1800's, and such forests still predominate today. In another 100 to 150 years, the watershed will again be covered by flammable, late successional forests, and another extensive fire or series of closely spaced fires probably will once more burn much of the watershed. Thus the subalpine plateaus of Yellowstone National Park appear to be characterized by a fire cycle in which areas up to 25,000 acres (10 000 ha) are burned at intervals of 300 to 400 years, with few large fires during the interim.

These cyclic changes in the vegetation mosaic may have important effects on wildlife habitat, stream flow, nutrient cycling, and other ecological processes and characteristics. Reconstruction of possible breeding bird populations and of elk habitat during the past two centuries suggests the existence of natural cyclic patterns that parallel the changes in vegetation. Managers should consider such dynamic properties of wilderness ecosystems when assessing the impact of past human disturbance and in developing wilderness management programs.

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FIVE-YEAR REVIEW OF FIRE IN THE MOOSE CREEK RANGER DISTRICT, SELWAY-BITTERROOT WILDERNESS

James Saveland and Richard Hildner

ABSTRACT: The Moose Creek Ranger District 5-year review of fire includes a summary of fire occurrence, the method of tracking fires, problems that have arisen, meeting objectives, and a look at the future. Fire occurrence is summarized in map and table forms. Information on size, location, duration, status, and the energy release component at ignition is presented, and the 3-day mean of the energy release component for each year is charted.

Ongoing fires are traced by a system of map pins, names, and numbers in 1979 to the locator system presently used and on display. Three categories of fire are currently used: active prescribed fires, inactive prescribed fire, and wildfire. The advantages to the locator system are that the system can handle a large fire load, the information for tracking wildfire and prescribed fire is in one location, the fire load and status are still graphically displayed. A single log is kept on each fire, which facilitates data entry and retrieval.

Some trail maintenance problems have resulted from prescribed fires. Structures such as water bars and log cribs have burned out, creating long- and short-term increases in trail maintenance costs. An increase in wind-thrown and fire-damaged trees across trails has increased the cost of clearing system trails.

Some smoke management problems have been associated with fires in the Moose Creek District. Smoke intrusions have not yet become a major problem, but active public involvement is still necessary to prevent misunderstanding about smoke. Smoke has caused some visitor inconvenience locally but has not yet become a major off-site concern; however, the potential for major off-site impacts is ever present.

An alternative objective that is quantifiable is presented: maximize the area that would be burned each year by naturally occurring lightning fires without man's intervention. Fire history studies can determine the upper limit and several management constraints which may or may not be binding are placed on the objective function. The average number of acres burned per year compared to the historical level, and the percent of lightning fires that are declared prescribed fires measure the performance of the prescribed fire program.

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FIRE REGIME OF THE LODGEPOLE PINE COMMUNITIES OF THE SAN JACINTO MOUNTAINS, CALIFORNIA

Paul R. Sheppard and James P. Lassoie

This study examines the effects of fire within the lodgepole pine (*Pinus contorta* var. *murrayana*) communities of the Mt. San Jacinto State park Wilderness, Calif. Lodgepole pine dominates on 8,150 acres (3 300 ha) of the wilderness and associates with white fir (*Abies concolor*) from 8,400 to 9,400 ft (2 560 to 2 865 m) elevation, and with limber pine (*Pinus flexilis*) from 9,400 to 10,800 ft (2 865 to 3 290 m) elevation. Fire scarred trees were sampled at 152-ft (500-m) intervals along transects that were 76 ft (250 m) apart; samples included all representative elevations, aspects, and slopes. We accepted two increment cores that showed a definite charcoal deposit and had no curved, repeating rings. We used a 0.1-acre (0.04-ha) plot, centered around the fire tree, to measure species composition and downed woody fuel loadings.

Preliminary data show that fires were mostly single-tree burns and that the average fire interval for all lodgepole communities from 322 to 3 years before present was approximately 25 years. At lower elevations, the greater the interval since the last fire the greater the importance of white fir basal area compared to that of lodgepole pine. At higher elevations, the length of the interval since the last fire apparently does not change the respective basal area importance of lodgepole pine and limber pine. Downed woody fuel loading generally increases as the interval since the last fire increases.

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FUEL CLASSIFICATION IN ASPEN FORESTS 11.

Dennis G. Simmerman and James K. Brown

This poster display illustrates the current development of fuel classification in aspen forests. Fuels and flammability vary considerably among aspen and mixed aspen/conifer forest types, depending upon plant community type, grazing influence, and quantities of downed woody material. The classification is based on these factors and permits managers to appraise rate of spread, fireline intensity, and likelihood of successfully using prescribed fire. Quantitative fuel information for each classification is also available and is useful in mathematical modeling of fire behavior. The classification's primary use is in planning prescribed fires and fire suppression activities.

Five overstory/understory cover classes have been delineated based on sample fuel loadings and modeled fire behavior for common community types found on the Bridger-Teton, Caribou, and Targhee National Forests: (1) Aspen/Shrub, (2) Aspen/Tall Forb, (3) Aspen/Low Forb, (4) Mixed/Shrub, and (5) Mixed/Forb. Differences among the classes are illustrated in the following tabulation of fine fuel loading and modeled fire behavior.

Fine fuels include herbaceous materials, shrubs, and downed woody material less than ¼ inch in diameter. A midflame windspeed of 6 m.p.h and fine fuel moisture contents of 8 percent were used in the fire behavior modeling, table 1.

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Table 1.--Fuel and fire behavior representative of aspen fuel classes

	Aspen			Mixed	
	Shrub	Tall forb	Low forb	Shrub	Forb
Fine fuel loading (lb/acre)	4,580	1,600	840	3,720	650
Rate of spread (ft/min)	11.1	6.5	2.6	3.4	2.2
Flame length (ft)	3.3	2.4	1.4	1.7	1.1

This tabulation represents average differences. Loading and fire behavior can vary substantially within classes, especially within the shrub and tall forb groups. This must be kept in mind when applying the classification to individual sites.

Flammability of each fuel class can be modified by grazing and accumulation of downed woody fuels. The tentative probabilities of successfully burning in these forest types and the influence of both grazing and woody fuel accumulation on the probabilities, are listed in table 2.

Table 2.--Adjective probabilities of successfully applying prescribed fire in aspen forests

	Aspen			Mixed	
Condition	Shrub	Tall forb	Low forb	Shrub	Forb
Ungrazed, light downed woody	Good	Fair	Poor	Good	Fair
Ungrazed, heavy downed woody	Good	Fair	Poor	Good	Good
Grazed, light downed woody	Fair	Poor	Poor	Fair	Fair
Grazed, heavy downed woody	Good	Poor	Poor	Good	Fair

Good: adequate burning conditions occur yearly.
Fair: adequate burning conditions occur every few years.
Poor: adequate burning conditions occur infrequently.

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A FIRE CHARACTERISTICS CHART FOR INTERPRETING MODELED FIRE BEHAVIOR IN ROCKY MOUNTAIN NATIONAL PARK

Thomas V. Skinner, Michael W. Hilbruner, Richard D. Laven, and Philip N. Omi

ABSTRACT: Using Northern Forest Fire Laboratory (NFFL) fuel models appropriate for Rocky Mountain National Park, we simulated fire behavior, interpreted the fire behavior results with the fire characteristics chart, and found that different models occupied different regions of the chart. Our results illustrate regions of expected fire behavior in the selected fuel models and should aid future fire management planning in Rocky Mountain National Park.

INTRODUCTION

Fire management in the national parks requires substantial background data from several areas of inquiry, among them, an assessment of potential fire behavior. In this paper, we describe simulated fire behavior for the fuel models that we consider applicable to Rocky Mountain National Park (RMNP). We used the fire characteristics chart, first published in Burgan (1979b), to interpret fire behavior results because it assimilates several fire behavior descriptors into an easily understood graphic format. Our analysis shows that the fuel models selected for RMNP occupy distinct regions of the fire characteristics chart and identify model-specific limits of fire behavior characteristics. These results should aid future fire management planning for RMNP by delineating the limits of fire behavior potential for each model and by specifying which fuel models and what conditions may lead to erratic fire behavior or potential fire control problems.

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Study Area

Rocky Mountain National Park straddles the Continental Divide and is located approximately 55 mi (85 km) northwest of Denver. The total land area of the Park is 412 mi^2 (1 080 km^2), and elevation varies from 7,620 to 14,255 ft (2 322 to 4 345 m). Forest vegetation at the lower elevation consists mostly of ponderosa pine (*Pinus ponderosa* Laws) and Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco), but as elevation increases, lodgepole pine (*Pinus contorta* var. *latifolia* [Engelm.]) forests become more abundant. Engelmann spruce (*Picea engelmannii* Parry) and subalpine fir (*Abies lasiocarpa* [Hook.] Nutt.) dominate the higher-elevation forests up to tree line, approximately 11,000 ft (3 350 m), above which is primarily the alpine tundra ecosystem. Groves of quaking aspen (*Populus tremuloides* Michx.) and limber pine (*Pinus flexilis* James) are scattered throughout much of the forested land within the Park but form no distinct, altitudinally bounded forest zones.

Literature Review

Rothermel (1972) developed a fire spread model that Albini (1976b) used to predict fire behavior in a set of 13 fuel models (hereafter called the Northern Forest Fire Laboratory [NFFL] fuel models). Anderson (1982) developed a pictorial key that, along with the key and descriptions included in the Fire Behavior Officer's (FBO) Field Guide (BIFC 1981), facilitates the proper selection of fuel models. The fire characteristics chart (Burgan 1979b) uses fire behavior descriptors of rate of spread, heat output per unit area, and fireline intensity or flame length to identify thresholds of potential fire control problems and thresholds beyond which fire behavior becomes erratic. Andrews and Rothermel (1982) encourage the use of the fire characteristics chart for comparing different burning conditions, comparing different fuel models, preparing fire prescriptions, or understanding fire behavior forecasts.

Several methods exist for generating fire behavior descriptions, but most are limited to use of a single set of environmental parameters for each generation of a description (Albini 1976a, 1976b;

Burgan 1979b). Hilbruner and Omi (1983) describe a computer routine (BRNPLN) that derives prescriptions based on combinations of fuel moisture, windspeed, and slope that lead to user-specified ranges of fire behavior descriptors, such as flame length, rate of spread, or heat output. The BRNPLN routine has an option that employs the NFFL fuel models and prints both fire behavior outputs and each combination of input parameter values.

METHODS

We used two fuel model keys and their accompanying descriptions to select the appropriate NFFL fuel models (BIFC 1981; Anderson 1982). We selected fuel models 2, 8, 9, and 10 from the set of 13 NFFL models to represent the fuels associated with the forests in RMNP. Models 2 and 9 both represent ponderosa pine stands differing in their fuel bed components (model 2 has a live fuel class, model 9 does not), their loadings by size class, and their fuel bed depth (model 2 is deeper than model 9) (Albini 1976b). Fuel models 8 and 10 represent lodgepole pine, Douglas-fir, and the spruce-fir forests. Model 10 has increased fuel loadings and an increased fuel bed depth when compared to model 9 in addition to the inclusion of a live fuel class, absent from model 9 (Albini 1976b).

The BRNPLN option we used allows each input parameter (fuel moisture by size class, windspeed, and slope) to vary for the calculation of fire behavior outputs (Hilbruner and Omi 1983). Albini (1976b) specified a moisture of extinction for the dead fuel classes in each fuel model; thus we let fine fuel moisture vary from 1 percent up to the model's moisture of extinction. Using the guidelines in the FBO Field Guide (BIFC 1981), we allowed live fuel moisture to vary from 50 percent to 300 percent. We varied windspeeds from 0 to 20 mi/h (0 to 32.2 km/h) (measured at midflame height), which, based on reduction factors (BIFC 1981), correspond to windspeeds exceeding 80 mi/h (130 km/h) measured at 20 ft (6.1 m) above the dominant vegetation. Because topographic maps for RMNP indicate that slopes rarely exceed 100 percent in the forested regions, we let slope vary from 0 to 100 percent by 10 percent increments.

The BRNPLN routine generated fire behavior descriptors associated with each combination of input parameters. We eliminated those combinations that exceed the reliable windspeed limit (when the ratio of reaction intensity to windspeed is less than 0.9 [Rothermel 1972]) and then selected those combinations that develop flame lengths of 4, 8, and 11 ft (plus or minus 0.1 ft) (1.2, 2.4, and 3.4 m). We plotted 4-, 8-, and 11-ft (1.2-, 2.4-, and 3.4-m) flame length curves for each fuel model on the fire characteristics chart. We used an analysis of variance (AOV) and Student's t test to assess whether the input parameter means were significantly different for the selected flame lengths.

RESULTS

The fire characteristics chart (fig. 1) includes the 4-, 8-, and 11-ft (1.2-,2.4-, and 3.4-m) flame length curves for models 2, 9, and 10. Because fuel model 8 did not develop any flame lengths exceeding 3.2 ft (0.98 m), we could not plot any flame length curves for model 8 nor could we subject model 8 to analysis in our statistical design. Table 1 displays the means and standard deviations of the input parameters that develop flame lengths of 4, 8, and 11 ft (1.2, 2.4, and 3.4 m) for fuel models 2, 9, and 10. An AOV test was significant ($P<0.01$) for all parameter means in all fuel models. Our Student's t test (table 2) suggests which input parameter sample means differ significantly ($P<0.2$) for the three fuel models.

DISCUSSION

Superimposing flame length curves for the selected fuel models onto the fire characteristics chart identified model-specific regions of the chart. Fuel models 2 and 9 develop fire behavior consisting of low heat output and moderate-to-high rates of spread; fuel model 10 generates high heat output values with low-to-moderate spread rates; and fuel model 8 develops both low spread rates and low heat output values. Although the model-specific regions of the chart overlap somewhat, our simulations delineate regions beyond which fire behavior for particular fuel models is unlikely.

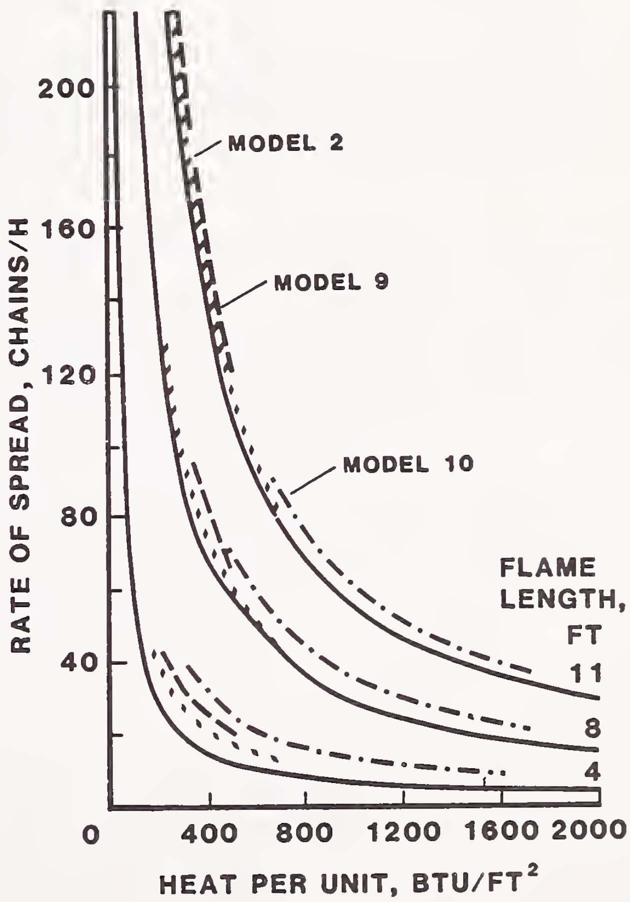

Figure 1.--Flame length curves of 4, 8, and 11 ft (1.2, 2.4, and 3.4 m) for NFFL fuel models 2, 9, and 10 on the fire characteristics chart (Burgan 1979b).

Table 1.--Means and standard deviations (s.d.) of input parameter that develop flame lengths of 4, 8, and 11 feet in NFFL fuel models 2, 9, and 10

Model		Fine fuel moisture			Live fuel moisture			Windspeed midflame height			Slope		
		4	8	11	4	8	11	4	8	11	4	8	11
		- - - - Percent - - -			Fraction dry weight			- - Miles/hour - - -			- - - - Percent - - -		
2	n	179.0	177.0	190.0	179.0	177.0	190.0	179.0	177.0	190.0	179.0	177.0	190.0
	mean	8.8	7.3	7.3	2.0	1.7	1.8	2.9	6.9	11.5	41.6	59.7	56.3
	s.d.	3.9	4.0	3.7	.8	.9	.8	2.7	3.9	4.0	24.9	28.3	30.3
9	n	68.0	18.0	3.0				68.0	18.0	3.0	68.0	18.0	3.0
	mean	11.6	5.0	2.0				8.5	15.8	17.7	58.7	70.0	66.7
	s.d.	5.4	2.2	.0				3.3	3.2	.6	30.1	21.7	20.8
10	n	204.0	167.0	69.0	204.0	167.0	69.0	204.0	167.0	69.0	204.0	167.0	69.0
	mean	13.0	10.2	7.7	2.1	1.6	1.1	8.3	13.5	15.7	47.0	54.4	51.7
	s.d.	6.1	50.9	5.6	.8	.8	.2	6.6	4.7	3.9	29.9	30.5	34.1

Table 2.--Student's t statistics, their associated probabilities (p), and each test's degree of freedom (d.f.) comparing sample means in table 1[1]

	Model 2				Model 9		Model 10			
	4 vs. 8 ft d.f. = 354		8 vs. 11 ft d.f. = 365		4 vs. 8 ft d.f. = 88		4 vs. 8 ft d.f. = 369		8 vs. 11 ft d. f. = 234	
	t	P	t	P	t	P	t	P	t	P
Fine fuels	3.6	<0.01	- 0.1	0.93	7.9	<0.01	4.4	<0.01	3.1	<0.01
Live fuels	3.2	< .01	.5	.61			6.3	< .01	5.8	< .01
Windspeed	-11.1	< .01	-11.1	< .01	-8.6	< .01	-9.0	< .01	-3.7	< .01
Slope	- 6.4	< .01	1.1	.30	-1.8	.08	-2.3	.02	.6	.60

[1]We did not test 8- versus 11-ft flame lengths for model 9 because the 11-ft sample consisted of only three data.

The ranges of fuel moisture used for the BRNPLN runs resulted in delineation of the upper and lower limits of heat output for the four selected fuel models. For each combination of fuel moisture content by fuel size class, a minimum rate of spread exists corresponding to the rate of spread with zero windspeed and no slope. Rate of spread increases as windspeed, slope, or both increase. Burgan (1983) uses effective windspeed, which combines slope with windspeed, to establish the maximum reliable effective windspeed limit. We did not use the effective windspeed; instead we used midflame windspeed, as suggested by Rothermel (1972), to determine if the reliable windspeed was exceeded. Therefore, no limit to slope exists in our analysis.

The model-specific fire behavior characteristics indicate each model's properties of fuel bed depth, loadings by size class, surface-area-to-volume (SA/V) ratio of each fuel size class, and presence or absence of a live fuel class (Albini 1976b). Specifically, model 2's high SA/V ratio in fine fuels and low fuel loadings in large fuel classes contributes to high rates of spread. Model 9 develops analogous fire behavior characteristics because of similar SA/V ratio in fine fuels; however, model 9's lack of live fuels and diminished fuel bed depth limits the potential range of heat output and rate of spread. Model 10's high loadings in the larger fuel sizes contribute to the high heat output, whereas the low SA/V ratio for the fine fuels decreases the potential rate of spread. Of the four models we selected, model 8 has the lowest fine fuel SA/V ratio and lowest fuel loadings, which combined with the low fuel bed depth causes fire behavior with low rates of spread and low heat output. The importance of the fine fuel SA/V ratio reflects the spread model emphasis that fine fuels carry the fire (Rothermel 1972).

We used the flame length curves in the fire characteristics chart as the basis of our analysis because they identify thresholds of fire control difficulty and potentially erratic fire behavior such as crowning or spotting (Burgan 1979b). We feel that the fuel moisture means for fuel models 2 and 10 in table 1 reflect moderate conditions even when 8- or 11-ft (2.4- or 3.4-m) flame lengths develop; however, the relatively high

standard deviations reflect the presence of many occurrences of low fuel moistures. The effects of the live fuel component on fire behavior takes on added meaning when considering the seasonal change in live fuel moisture (Burgan 1979a). Thus, fuel models 2 and 10 can develop higher fire intensities as the season progresses, all other parameters being unchanged. Mean windspeed shows a trend of increasing values for all fuel models and all flame lengths. Mean values for slope increase between 4- and 8-ft (1.2- and 2.4-m) flame lengths but decrease between 8- and 11-ft (2.4- and 3.4-m) flame lengths for reasons that are not clear.

Table 2 shows that all input parameter sample means differ significantly when comparing 4- to 8-ft (1.2- to 2.4-m) flame lengths. When comparing 8- to 11-ft (2.4- to 3.4-m) flame lengths, however, only windspeed differed significantly in fuel model 2, while in fuel model 10, all parameters but slope differed significantly. Our method of analyzing the sample means did not consider how fire behavior changes while varying only one parameter. Thus, explanation of the failure of some input parameters to differ when comparing 8- to 11-ft (2.4- to 3.4-m) flame lengths remains obscure.

The lack of analysis of fuel model 8 reflects its limited potential to develop high fire intensity because of low fuel loadings and small fuel bed depth. Fuel model 8 develops flame lengths reaching a maximum of 3.2 ft (0.98 m) because this model exceeds the windspeed limit at 12 mi/h (19.31 km/h) (measured at midflame height), thus eliminating almost half of our behavior iterations. Because this fuel model represents forest types that often create fire control difficulties and develop erratic fire behavior, an apparent contradiction exists. This contradiction may reflect fuel conditions more like fuel model 10, which also represents these forest types, fuels that violate the assumption of a homogeneous fuel bed with uniform depth, or a need for custom fuel modeling.

We limited our analysis to fuel models representative of RMNP. We selected NFFL fuel models 2 and 9 to represent ponderosa pine stands and models 8 and 10 to represent stands of Douglas-fir, lodgepole pine, and spruce-fir forests. Our results apply to any location where these forest types occur and the corresponding fuel models apply. In addition, other vegetation types that use any of the fuel models we analyzed will develop fire behavior similar to our simulations and, therefore, our conclusions also apply to them.

Future fire management plans for RMNP should reflect our results. Fire behavior results for fuel models representative of the lower-elevation ponderosa pine and Douglas-fir forests, where most of the development of the Park exists, point out the potential of fire control problems. Additionally, our results suggest a similar likelihood of erratic fire behavior in the high-elevation forests of RMNP, as evidenced by the Ouzel Fire (Laven 1980; Butts this proceedings). Although RMNP has experienced mostly small fires during the recent past (Clagg and Stevens 1976), our results show that the potential exists for fire control problems and erratic fire behavior in all forest types included within the Park's boundaries and in three out of the four selected fuel models.

CONCLUSIONS

We found that each of the NFFL fuel models we chose (2, 8, 9, and 10) develop fire behavior occupying distinct regions, rather than any possible region of the fire characteristic chart. Although fuel model 8 did not develop flame length values greater than 3.2 ft (0.98 m), the other three models we selected all developed flame lengths up to 11 ft (3.4 m). We believe that our simulations delineate maximum and minimum heat output values associated with each model. Using flame length to identify thresholds of fire control difficulty, we characterized the input parameters of fuel moisture, windspeed, and slope that contribute to fire behavior at these threshold conditions. Windspeed consistently contributes to fire behavior differences in all three fuel models tested. Fuel moisture contributes to differences between 4- and 8-ft (1.2- and 2.4-m) flame lengths but only partially in differences between 8- and 11-ft (2.4- and 3.4-m) flame lengths. Our results point out the potential of developing erratic fire behavior in all forest types found in RMNP and in three out of four fuel models.

ACKNOWLEDGMENTS

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245 INITIAL STAGES OF A NATURAL FOREST SUCCESSION FOLLOWING WILDFIRE IN THE NORTHERN ROCKY MOUNTAINS, A CASE STUDY

Peter F. Stickney

Left to its own, how does a Northern Rocky Mountain forest, undisturbed by logging or other activities of people, respond and regenerate when destroyed by wildfire? What species present in the initial community were important to the development of the early seral vegetation and which of the successional processes, relay floristics or initial floristics, appears to be operating in the development of the initial stages of secondary forest succession in the Northern Rocky Mountains? An opportunity to provide some answers to these questions occurred on August 23, 1967, at Miller Creek in the Flathead National Forest when a wildfire burned a *Larix occidentalis-Pseudotsuga menziesii* forest. In addition to a cone-bearing overstory, the 200- to 250-year-old stand had an understory of *Vaccinium globulare* (54 percent cover) and *Xerophyllum tenax* (23 percent cover).

Because it burned under extreme fire danger conditions with the lower half of the duff quite dry (56 percent moisture content), the fire effect was severe enough to kill all overstory and understory trees, burn all shrubs and herbs back to the ground, and reduce the litter-duff layer to ash on mineral soil.

Half of the 23 plant species comprising the preburn community were killed by this fire, and most of the surviving species experienced high mortality levels. In addition to the five conifer species present, the largest group of nonsurvivors were shade-adapted herbs typically associated with late seral and climax forest communities. Typical species in this group are *Chimaphila umbellata*, *Goodyera oblongifolia*, *Listera caurina*, and *Linnaea borealis*.

The initial plant community formed the first year after the fire consisted of two groups: species that survived the fire and regrew from burned root crowns or underground plant structures (rhizomes, bulbs, caudexes) and species that were present as newly established seedlings. Survivor species important to early succession included *Spiraea betulifolia* and *Xerophyllum tenax*. *Acer glabrum* and *Vaccinium globulare*, the two most abundant shrubs in the 200-year-old forest, also survived but suffered high mortality and contributed little to the cover of early seral vegetation.

The colonization of four species of the postfire seedling group accounted for most of the vegetation cover developed during the next 14 years. These species were *Epilobium angustifolium*, *Ceanothus velutinus*, *Pinus contorta*, and *Larix occidentalis*.

In the seral development following the establishment of the initial community, herbs constituted the most abundant life form from the 2nd to the 5th year of succession. Most of the herb cover during this period was attributed to *Epilobium angustifolium*. From the 6th through the 15th year, shrubs were the most abundant life form cover group. Throughout this period, *Ceanothus velutinus* remained the principal shrub, forming nearly a closed shrub layer by the 13th year (coverage of 94 percent). Although the two most important seral tree species (*Pinus contorta* and *Larix occidentalis*) germinated and established seedlings in the first year, their cover development has been slower.

By the 15th year, tree cover was about half that of shrub cover and three and a half times that of herb cover. In contrast to cover, the development of tree height has exceeded height growth for shrubs since the 7th year at the beginning of the shrub stage. Thus, most of the cover development for pioneer tree species has taken place above the general shrub canopy. With the continued increase in tree crown cover, cover of *Ceanothus velutinus*, a shade-intolerant shrub, is expected to decline, possibly within the next 5 to 10 years. Cover of the herb component under and within the shrub layer has remained essentially stable since the advent of the shrub stage. The abundance of *Epilobium angustifolium*, *Xerophyllum tenax*, and *Calamagrostis rubescens*, the three most abundant herb species, has changed little during this period, and little change is anticipated in the immediate future.

Over the first 15 years of succession, the sequential development of dominant community components has proceeded from herb (years 2 to 5) to shrub (years 7 to 15+) stages by the development of species that were all present in the first year. Present trends indicate that the same is true for the tree component and that the start of a tree stage, possibly in 5 to 10 years, will result from the development of tree species also present in the first year of succession. Up to this time, no introduction of secondary colonizer species with the potential to alter the successional sequence

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has been documented or observed. It appears at this point that the seral process operating in the early phase of succession at the Miller Creek wildfire site is based on differential development of members of the initial community.

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FIRE-CAUSED MORTALITY IN CHAMISE CHAPARRAL

Thomas J. Stohlgren

ABSTRACT: Fire-caused mortality and reproductive potential are used to evaluate fire management alternatives in chamise chaparral. Although frequency of burn mortality is highest in small shrubs, the probability of burn mortality is highest in large shrubs. Years of fire suppression may not have significantly affected chamise reproduction potential.

INTRODUCTION

Pure stands of chamise (*Adenostoma fasciculatum*) chaparral in the foothills of Sequoia National Park, Calif., are periodically rejuvenated by fire. Chamise is adapted to rapid recovery after fire by resprouting and seeding (Laude and others 1961; Radosevich and others 1977; Baker and others 1982).

Since the Park was established in 1890, the primary management objective for the chaparral zone has been to suppress all fires. In recent years, U.S. Department of the Interior, National Park Service, has reintroduced fire in chaparral by prescribed burning[1] (Parsons 1981). The primary objectives of the Park's fire management program for the foothill zone are to reduce hazardous fuels that have built up naturally or because of fire suppression and to reintroduce the natural role of fire to these fire-evolved ecosystems.

An understanding of the ecology of these natural systems is necessary to evaluate the effects of previous management practices (suppression) and current practices (prescribed burning). Previous research on chamise chaparral ecology in the Park has included studies of structural changes in chamise along fire-induced age gradients (Rundel and Parsons 1979), postfire demography and succession (Rundel 1982; Rundel and others 1983), and population dynamics (Stohlgren and others 1984). A method for determining a shrub's dry weight from its stem basal area (Stohlgren and others 1982) has been used to determine stand biomass (or dry fuel loading), stand structure (percent of individuals by size class), and suppression mortality by size class for mature chamise stands in Sequoia National Park. Biomass in mature (>60-year-old) stands was found to range form 8.9 to 23.2 tons/acre (20 000 to 52 000 kg/ha) with a mean of 13.7 tons/acre (30 700 kg/ha). Mature stands exhibited a negative exponential size class distribution with 60 percent of the individuals in the 0- to 11-lb (0- to 5-kg) dry weight size class, 23 percent in the 11- to 22-lb (5- to 10-kg) class, and tapering to just 1.2 percent in the >55.1-lb (>25-kg) size class. In four mature stands, suppression mortality averaged 16 percent and was concentrated in the smaller size classes of individuals.

Rundel and others (1983) have shown how fire seasonability and intensity affect resprouting and seedling establishment. Their work provides managers with a basis for planning. These techniques enable managers to compare the effects of prescribed burns on chamise population structure when conducted in the fall and spring and under low and high intensities.

The purpose of this report is to quantify the effects of mortality due to natural thinning and fire-caused mortality in mature chamise stands and to show how such information can help evaluate the relative impacts of suppression and prescribed burning. Results of preliminary studies to determine how chamise reproduction may have been affected by years of fire suppression are also reported.

METHOD

The study area is located in the low-elevation foothills of Sequoia National Park, Calif. Pure chamise stands were identified in areas that fire history maps indicated had burned once in the past 2 years but had not burned in the 60 years previous to the recent burn.

The seven 32.8 by 32.8 ft (10 by 10 m) plots were randomly located in three burned areas. Four of these plots were located in areas that had been prescribed burned in late November and December;

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[1]Editors' note: please refer to the Foreword for comments on prescribed fire terminology.

the other three plots were located in two August wildfires (arson and accidental ignitions). The basal diameters of the charred (but standing) stems of each shrub were measured to estimate the shrub preburn dry weight (Stohlgren and others 1982). Records were also kept on whether the shrub had resprouted or was dead. Data on mortality due to natural thinning were taken from previous studies of unburned mature stands (Stohlgren and others 1984).

In July 1983, three live individuals in a >60-year-old stand and seven individuals in a 22-year-old stand were measured for estimated preburn biomass, and all inflorescenses were removed and dry weighed. Only shrubs in full bloom were sampled at each site. Six subsamples of 0.7 oz (≅20 g) were separated into flowers and stocks, and 100 flowers from each subsample were counted and weighed to estimate the total number of flowers from each of the 10 shrubs.

RESULTS AND DISCUSSION

Figure 1 indicates the percent mortality due to natural thinning and due to fire. To separate the causes of mortality, natural thinning mortality (found in unburned stands) was subtracted from total mortality found in postburn stands. For example, the mean percent mortality due to thinning in the 0- to 11-lb (0- to 5-kg) size class was found to be 29.7 percent (Stohlgren and others 1984); total mortality in the postburn plots studied here have averaged 35.9 percent in the same size class. This represents a 6.2 percent fire-caused mortality. In the larger size classes, where no thinning mortality was observed, all mortality can be expressed as fire-caused.

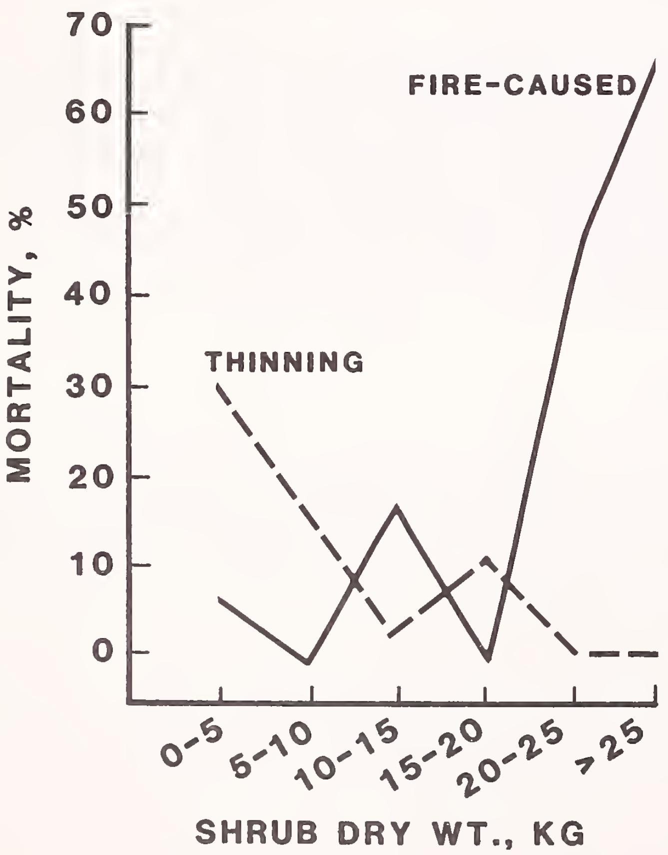

Figure 1.--Percent mortality by size class in chamise.

These findings indicate the size class most likely to avoid mortality is the middle of the size class distribution range, where shrubs are less susceptible to thinning and fire-caused mortality. Large preburn shrubs (less than 5 percent of the population) may have more dead material in them from surviving several previous fires and thus may be more likely to be killed by fire. Much of the thinning mortality in the smallest size class may occur among seedlings suppressed following the last fire and outcompeted by faster growing resprouts.

Prescribe burning additional chaparral areas may be either to reduce fuels to meet specific management objectives (for example, visitor safety and wildlife habitat management) or to augment natural ignitions (those suppressed during high fire danger periods or those that would have originated outside the park). Managers must know the range of times and conditions when prescribed burning will best approximate the effects of natural lightning fires, which commonly occurred in August and September (Parsons 1981). In the burns studied there appears to be a difference in shrub mortality between August (40 percent mortality) and November-December (19.7 mortality) fires. Managers must weigh the trade-offs of prescribed burning areas under cooler, safer, late-year conditions with burning during hot, dry conditions and accept atypically low mortality in order to approximate the effects of a natural process (which may have more frequently occurred in August.).

To evaluate the effects of different fire management alternatives, managers must determine how each affects mortality and reproduction of the populations in question. Years of continual fire suppression in a resprouting population should alter species survival (Keeley and Zedler 1978). In the recently burned mature chamise stands studied here, total mortality is still low (≅30 percent). These postfire stands have also shown vigorous resprouting and reseeding (Rundel and others 1983). It has been argued that years of fire suppression may have greatly altered some vegetation types in the Park (Bonnicksen and Stone 1982). This may not be as pronounced in chamise chaparral as in the sequoia-mixed conifer forests. In fact, suppression activities for such a flashy fuel type are not particularly effective. Parsons (1981) showed that even under a policy of total suppression 38.1 percent of the Park's chaparral burned between 1920 and 1978.

The reproductive effort in >60-year-old shrubs also indicates a vigorous population (fig. 2).

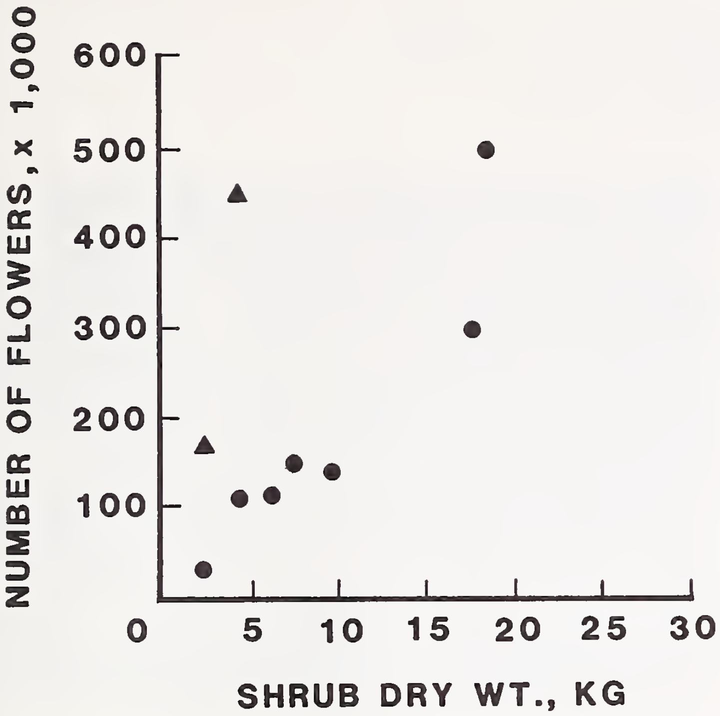

Figure 2.--estimated number of flowers by size class of chamise. points represented by triangles are from 60-year-old stands. All others are from a 22-year-old stand.

Preliminary results indicate larger and older shrubs produce more flowers per year than smaller younger shrubs. This area needs to be further studied because flowering differs among individuals observed in the field at different sites and at different times during the spring.

Research of this type is necessary to provide managers with a framework for evaluating different fire management alternatives. This approach can be expanded to other vegetation types only after a significant information base on population dynamics, fire history, fire behavior, and ecosystem processes is available.

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PUBLIC INVOLVEMENT IN WILDERNESS FIRE MANAGEMENT

John Swanson and Alan Denniston

ABSTRACT: A joint interagency fire management plan for Lassen Volcanic National Park and the Caribou Wilderness in northern California has served as the model for this poster session. The public has been involved throughout the planning stages and implementation.

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There are various approaches to involving the public in wilderness fire management. They include the use of news releases, personal newsletters, slide-tape presentations, workshops, television exposure, and signing. These media were used to educate, to inform, and to solicit the input of issues and concerns during planning and to educate, to inform, and to warn users of expected conditions during implementation. Success of a particular method of contact, measured on the basis of numbers responding, was varied. The most favorably received approach was the personal newsletter, public workshops proved least successful. In spite of the variability in the success of our public involvement efforts, public involvement helped us complete the plan, and we anticipate greater success in implementation than would otherwise have been possible.

OLD BURNS LIMIT SIZE OF FIRES

James N. Sweaney

Seral forests that persist for more than 100 years following a fire effectively limit the average size of forest fires in Yellowstone National Park. The Park consists of a large flat basin surrounded by mountains; this basin contains few permanent natural barriers capable of stopping an intense stand replacement fire. During the first 10 years of prescribed natural fire management, 20 of the 22 fires that exceeded 5 acres (2 ha) occurred in old-growth stands (spruce-fir or lodgepole pine [*Pinus contorta*] with an understory of Engelmann spruce [*Picea engelmannii*] and subalpine fir [*Abies lasiocarpa*]).

During the intense 1979 and 1981 fire seasons, we observed fires being retarded or stopped by old burns:

Astringent Fire: This was a 921-acre (373-ha) fire that burned in spruce-fir for over a month during a particularly hot 1981 fire season. Like most Yellowstone National Park fires, it was driven to the northeast by the prevailing wind. The northeast edge of the fire approached a fire scar that was revegetated with sapling-sized lodgepole pine. As predicted, the fire stopped when it encountered young timber even though burning conditions remained hazardous.

Sulphur Fire: The Sulphur Fire started August 2, 1981, and eventually burned 3,216 acres (1 302 ha) of old lodgepole with an understory of spruce, fir, lodgepole pine, and heavy down material. The fire made an initial run of 3 miles (4.8 km) in 2 days until it met the White Lake burn of 1953. The area burned increased fourfold as burning continued for 2 months under increasingly severe conditions along the base and flanks, but the sparse fuels left by the White Lake Fire completely stalled the downwind spread. Without this barrier, the Sulphur Fire could have burned to the northeast for 10 more miles (16 km).

Beaver/Heart Fire: A complex of fires in 1780, 1879, and 1910 burned most of the country between Heart Lake and the Flat Mountain Arm of Yellowstone Lake. Beaver Creek, a small stream that would normally be incapable of slowing a significant running fire, forms the west perimeter of the 1910 and 1879 burns. Apparently, these fires backed against the prevailing wind until they were stopped by the creek. The Beaver/Heart Fire, a 1979 prescribed natural fire, ignited west of Beaver Creek and quickly ran to Beaver Creek and the old burns. The eastern perimeter of the main Beaver/Heart burn is almost the same as the western perimeter of the older fires. Numerous spot fires, more than 2 miles (≅3 km) north and east of the main fire in the old burns, indicate that the fire would have crossed Beaver Creek and continued its rapid run to the northeast if the fuel had not been broken up by earlier fires. This same 1879 burn is responsible for containing the northerly spread of the Divide Fire--a 1976 prescribed natural fire that burned 1,500 acres (607 ha).

CONCLUSIONS

Old burns have apparently played a role in limiting the size of subsequent fires; they are useful to managers for predicting fire behavior and making decisions concerning the desirability of such fires. Without the variations and discontinuities in the fuel complex resulting from past large fires; we would presumably have larger fires.

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FIRE HISTORY OF PONDEROSA PINE FORESTS IN THE GILA WILDERNESS, NEW MEXICO

Thomas W. Swetnam and John H. Dieterich

ABSTRACT: Crossdating of tree-rings and fire scars on 44 cross sections of ponderosa pine *(Pinus ponderosa)* trees revealed that extensive surface fires were a common occurrence before 1900. Mean fire intervals from 1633 to 1900 were approximately 4 to 8 years, and fire intervals ranged from 1 to 26 years.

INTRODUCTION

In 1924 approximately 750,000 acres (303 500 ha) of the Gila National Forest were designated as the Nation's first Wilderness and Primitive Area within the National Forest System. Today, the Gila Wilderness, the nearby Aldo Leopold Wilderness, and adjoining primitive areas comprise one of the largest areas under wilderness protection in the United States. The Gila contains some of the most extensive stands of virgin ponderosa pine remaining anywhere within the widespread range of this species.

It is fitting that pioneer efforts to reintroduce fire in wilderness have occurred in the Nation's first wilderness area. Since 1975 approximately 12,000 acres (4 856 ha) have been burned by lightning-ignited, prescribed fires (see Webb, elsewhere in this volume). Although burning prescriptions and fuel models have been refined and monitoring techniques improved, the availability of basic information on the importance of fire to specific ecosystems within the Gila Wilderness has been lacking.

In the summer of 1980 we began a fire history research study to provide data for future wilderness fire management planning and to answer several pertinent questions within the framework of the Prescribed Natural Fire (PNF) Program (Swetnam 1983). We posed the following questions:

1. How often did fires burn within ponderosa pine areas of the Gila Wilderness before livestock grazing and fire suppression efforts began?

2. How large were presettlement fires?

3. Are prescribed natural fires frequent and large enough to simulate the presettlement fire regime?

To obtain information about the presettlement fire regime, we collected fire scar samples from ponderosa pine trees in three study areas, McKenna Park, Langstroth Mesa, and Gilita Ridge. These areas were chosen on the basis of proximity to approved PNF areas and accessibility. (Figure 1 shows the relative location of the study areas within the Wilderness and National Forest.) All three study areas are within the Petran Montane Conifer Forest biotic community (Brown 1982). The overstory within the study areas is pure ponderosa pine, and the understory is composed of various grass species such as *Festuca arizonica* and *Muhlenbergia virescens*. Portions of the study areas also have dense stands of *Pteridium aquilinum* and scattered groups of *Quercus gambelii*.

METHODS

We obtained 44 cross sections from collection sites within the three larger study areas. (Table 1 identifies general characteristics of the collection sites within each of the study areas.) The collection sites included areas of less than 100 acres (40.5 ha) each. Fire-scarred trees were sampled in clusters or groups of at least two trees because it has been found that a composite of fire scar records from nearby trees generally provides more complete information for an individual site than records from single trees scattered over a larger area (Dieterich 1980).

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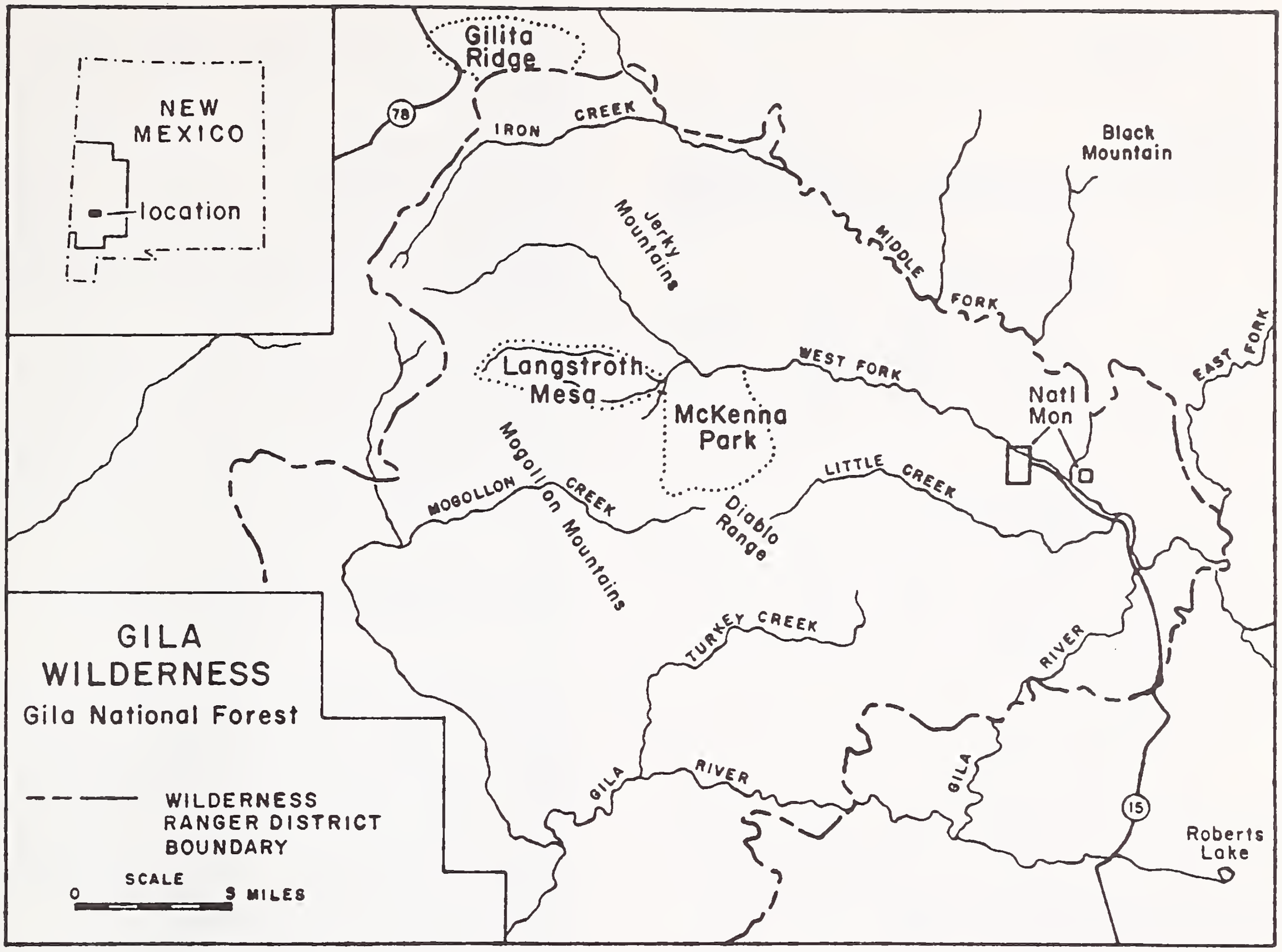

Figure 1.--Map of the Gila Wilderness.

All of the samples collected from the Wilderness were obtained by felling live and dead trees with a crosscut saw and then bucking off cross sections from the bole or stump. Samples were also obtained from downed logs. Fire-scarred material was packed out of the Wilderness by mule. Samples from Gilita Ridge, which is just outside the Wilderness boundary, were collected by using a chain saw to remove cross sections from stumps of trees recently felled during a timber harvest in the area.

Increment core collections were also obtained from each study area so that master tree-ring chronologies could be developed as dating controls. Two cores were taken from each of 15 to 20 trees in each of the study areas.

Increment cores were mounted in wooden holders, sanded, and crossdated as described by Stokes and Smiley (1968). The annual ring-widths of each core were then measured on a sliding stage micrometer interfaced with a microcomputer (Robinson and Evans 1980). The measured ring-width series was then standardized and averaged (Fritts 1976) using a series of computer programs (RWLIST, INDEX, SUMAC) (Graybill 1979).

The fire-scar samples were reduced in size with a bandsaw so that they could be conveniently observed under a microscope. Each cross section was carefully sanded with a power sander using belt grits from 40 to 400. The master tree-ring chronologies were then used as dating controls for dating annual rings of the fire-scarred specimens. They were considered controls because crossdating ensured that the master tree-ring chronologies, which were composed of measurements from many trees, included values for each year of the series, whereas ring series from individual trees may not be complete or accurate because rings may be false or absent in a particular area.

Crossdating is a preferred method of dating fire scars, especially in short fire interval types such as ponderosa pine (Madany and others 1982). The greater accuracy of crossdating is needed to distinguish between fire events that may occur as close together as 1 year. Precise fire dates are also necessary if analyses include comparisons between study areas or comparisons with climatic data because if fire dates are off by 1 or more years, possible correlations may not be observed. Crossdating also provides a means of determining fire dates from fire-scarred snags and downed logs.

Table 1.--Description of collection sites within study areas

Site	Number of specimens[1] L	D	T	Elevation feet	m	Topography Aspect	Slope Pct
				McKenna Park			
A	3	1	4	7,760	2 365	NE	0-5
B	5	1	6	7,800	2 377	SW	5-100
C	2	0	2	7,700	2 347	Flat	-
D	0	4	4	7,640	2 329	NW	5-20
	10	6	16				
				Langstroth Mesa			
A	5	0	5	8,000	2 438	N & S	5-10
B	1	3	4	7,800	2 377	Flat	-
C	2	2	4	8,400	2 560	E	0-5
D	3	2	5	7,800	2 377	Flat	-
	11	7	18				
				Gilita Ridge			
A	0	10	10	8,300	2 500	S	0-5

[1]L = live; D = dead (collected from snags, downed logs, and stumps); T = total.

After crossdating the ring series and fire scars of each sample, another dendrochronologist independently crossdated the samples as a check. All of the fire scar dates were then compiled for each specimen by collection site and study area, and the dates were included on a master fire chronology chart.

RESULTS

The master fire chronology charts for the McKenna Park, Langstroth Mesa, and Gilita Ridge study areas are shown in figure 2. The horizontal lines represent the life spans of individual fire-scarred trees and the arrowheads on either side of the lines indicate fire-scar dates from both sides of the cross section samples. Presentation of fire scar data in this form is useful because calculations of mean fire intervals (MFI's) alone do not indicate the inherent variability of a fire regime or the limitations of the MFI estimates. Mean fire intervals are the arithmetic average of fire intervals determined in a designated area during a designated time period (Romme 1980).

Several obvious features are apparent from inspection of the master fire chronologies. For example, the periodic recurrence of fires that scarred the sample trees ceased after about 1900. Another notable feature is the relatively consistent agreement of fire scar dates among the sample trees. It is also apparent that the most complete record of fire occurrence is for the period after 1800. Before 1800, fewer trees were alive or they had not yet been scarred by fire and were therefore less susceptible to scarring. Trees that have been scarred at least once have exposed cambium, and the pitch that exudes from the wound boundaries can be easily ignited. Such trees are termed fire-scar-susceptible trees (Romme 1980).

Tables 2 and 3 list the MFI computations for the three study areas by time period. The time periods were based on the characteristics of the records. For example, the 1801-1904 period in McKenna Park had the largest number of sample trees recording fires, whereas the 1633-1801 period had the fewest trees recording fires.

Because there was an obvious decline in the number of fires recorded after 1900, separate MFI's were computed for post-1900 periods.

The reason for computing MFI's for all fire years (table 2) and fire years recorded by more than one specimen (table 3) was to present the data in different perspectives. For periods after 1800, MFI's in table 2 are more representative of the time interval between any fire, while MFI's in table 3 are more representative of time intervals between larger fires. For periods before 1800 this distinction cannot be made because of the scarcity of fire scar evidence.

Mean fire intervals were computed for the 1837-1904 period in McKenna Park and Langstroth Mesa and for 1837-99 on Gilita Ridge because before 1837 there was a relatively long period in all three study areas when no fires were recorded by the sample trees. The length of this period was 12 years in McKenna Park (1825-37), 22 years on Langstroth Mesa (1815-37), and 18 years on Gilita Ridge (1819-37). Mean fire intervals are slightly shorter when this period is omitted from the computations.

DISCUSSION

Changes in the Fire Regime

Perhaps the most striking pattern observed in all three of the master fire chronologies was the sudden decrease in the number of fires recorded after 1900 by the sample trees (fig. 2). Only four fires were recorded in McKenna Park after 1904. Five fires were recorded by Langstroth Mesa specimens after 1904, and only one fire was recorded by Gilita Ridge specimens after 1899. Between the years 1640 and 1900, 58 fires were recorded in the three study areas (each fire recorded by at least two specimens).

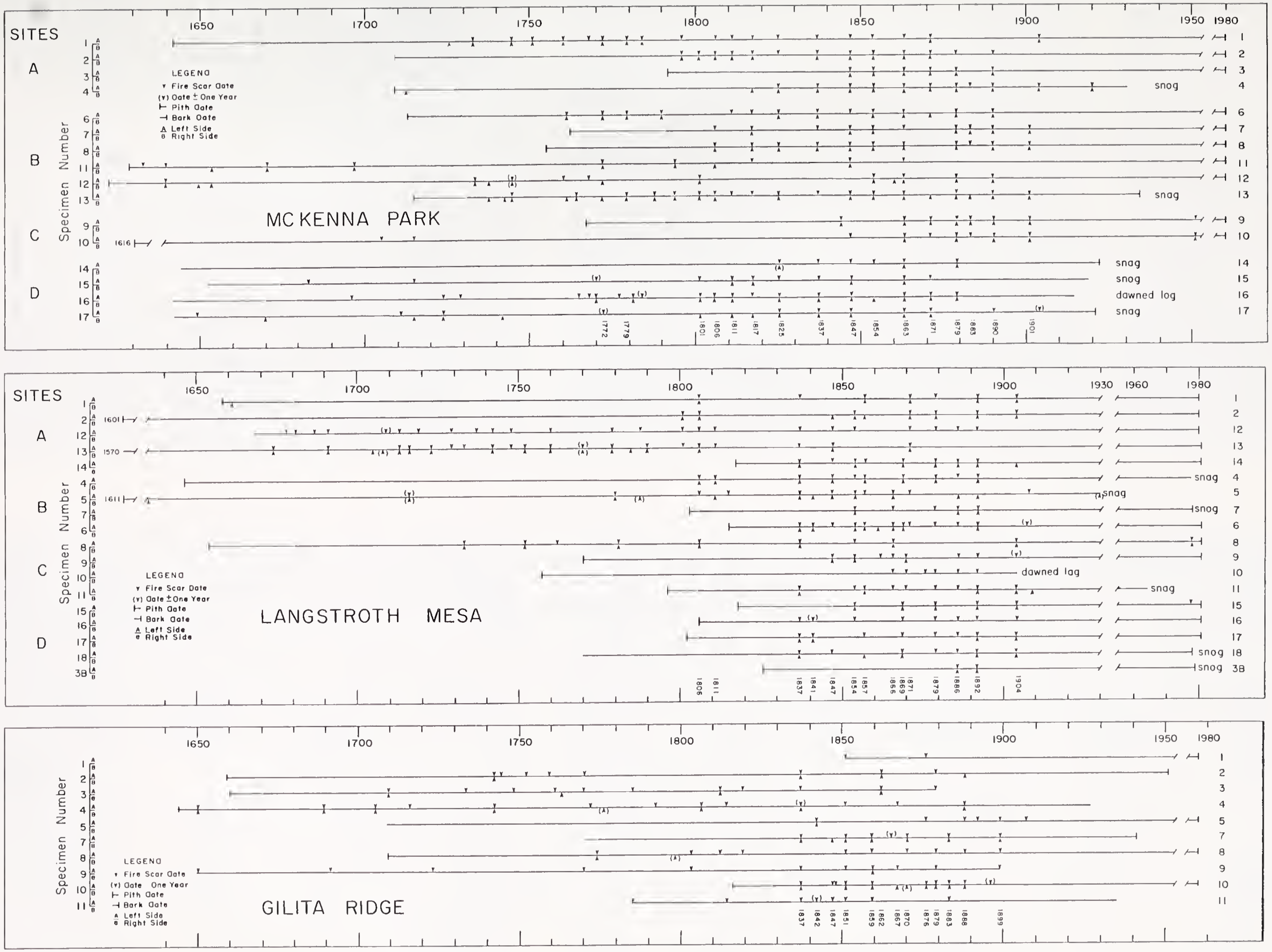

Figure 2. Master fire chronologies.

Table 2.--Mean fire intervals by study area and time period; all fire years included

Study areas and time periods	Fire interval Mean	Range	Number of fire-scar-susceptible trees[1]	Number of trees collected
	---years---			
McKenna Park				16
1633-1801	4.3	1-16	0/11	
1801-1904	6.4	3-12	11/16	
1837-1904	6.1	3-11	14/16	
1904-1951	23.5	16-31	16/16	
Langstroth Mesa				18
1635-1801	5.7	1-26	0/5	
1801-1904	5.4	1-22	5/18	
1837-1904	4.5	1-12	7/18	
1904-1978	14.8	1-48	18/18	
Gilita Ridge				10
1650-1803	16.9	2-39	0/6	
1803-1907	4.7	1-18	6/10	
1837-1907	4.1	1-8	6/10	

[1]The numerator is the number of fire-scar-susceptible trees at the beginning of the period, and the denominator is the number susceptible at the end of the period.

Table 3.--Mean fire intervals by study area and time period; fire years recorded by more than one sample tree included

Study areas and time periods	Fire interval Mean	Range	Number of fire-scar-susceptible trees[1]	Number of trees collected
	---years---			
McKenna Park				16
1640-1801	11.5	1-61	1/11	
1801-1904	7.4	3-12	11/16	
1837-1904	6.7	3-10	14/16	
1904-1951	47.0	-	16/16	
Langstroth Mesa				18
1691-1801	10.2	3-22	4/5	
1801-1904	6.9	1-26	5/18	
1837-1904	5.6	1-12	7/18	
1904-1978	74.0	-	18/18	
Gilita Ridge				10
1742-1803	20.3	15-28	3/6	
1803-1899	6.0	2-18	6/10	
1837-1899	5.2	3-11	6/10	

[1]The numerator is the number of fire-scar-susceptible trees at the beginning of the period, and the denominator is the number susceptible at the end of the period.

Several of the fires recorded after 1900 are documented by U.S. Department of Agriculture, Forest Service, records. For example, a 1951 fire that scarred specimens 9 and 10 in McKenna Park (fig. 2) was probably the 14,000-acre (5 670-ha) "Little Creek Fire." This fire was recorded only in collection site C. This assumption is reasonable because a map of this fire prepared by the fire boss after the fire was controlled shows that bulldozer firelines were constructed to the west of site C, which would have prevented the fire from spreading into any of the other collection sites.

The differences in fire regime before and after 1900 are also reflected in the MFI computations. For example, the MFI's for fires recorded by more than one sample for periods before 1900 are approximately 6 to 8 years in McKenna Park and 5 to 7 years on Langstroth Mesa and Gilita Ridge. For periods after 1900 the fire intervals are 47 years in McKenna Park, 74 years on Langstroth Mesa, and 82 years on Gilita Ridge. This evidence indicates that the fire regime that had persisted for centuries was essentially eliminated by the beginning of the 20th century. The decline of periodic fires was a direct result of a combination of human-induced changes. These changes included removing Apaches from the Gila area by the 1880's (since they probably started some fires), introducing thousands of sheep and cattle to the area beginning in the 1890's, and fire suppression efforts that began in the 1900's. The relationship of changes in land use to changes in fire regime has been recognized and discussed in many fire histories and other ecological studies (Leopold 1924; Weaver 1951; Cooper 1960; Arno 1980).

Areal Extent Of Pre-1900 Fires

Between the years 1801 and 1904, an average of 65 percent of the fire-scar-susceptible trees were scarred by each fire recorded in McKenna Park, and 62 percent were scarred by each fire recorded on Langstroth Mesa. Between 1803 and 1907, 42 percent of fire-scar-susceptible trees were scarred by each fire recorded on Gilita Ridge (computations include fire dates recorded by more than one tree). The agreement of fire dates among many of the sample trees and collection sites within the study areas (fig. 2) suggests that most fires burned throughout the study areas. These fires could have been caused by single or multiple ignitions.

It is also evident that some fires were more limited in area. For example, fires that burned in McKenna Park in 1844, 1860, 1920, and 1951 (the "Little Creek Fire") were recorded by only one or two specimens. The Langstroth Mesa master fire chronology demonstrates another example of the areal extent of past fires (fig. 2). Fires burned within the study area on three consecutive years--1869, 1870, and 1871; however, these fires did not burn over the same collection site in consecutive

years. In 1869, sites A, B, and D burned. These sites are all on the eastern side of the study area. In 1870, site C, located on the western side of the study area, burned over. Then, during 1871, fire again burned through sites A and B, although in site A this fire was recorded only by trees that were not scarred 2 years earlier. This pattern of burning suggests that the presence of adequate ground fuels was especially important in the timing and spread of fires. When fuels in one portion of the study area were not consumed by fire they were still available for burning the next year. Areas that had burned the previous year had not built up enough fuels to carry fire. Thus consecutive-year fires on the same site were unlikely to have occurred within the study areas, although fires occurring every other year (a 2-year interval) were confirmed. This pattern of burning also shows that although large fires were common for the pre-1900 fire regime, patchy burns also occurred occasionally, causing different amounts of fuel to be available at different locations.

Ignition Sources

The relative importance of Indian ignitions is unknown; however, the incidence of lightning fires in the Gila Wilderness is perhaps higher than in any other wilderness area in the National Forest System. Approximately 252 fires occur per million protected acres per year (Barrows 1978). Therefore, an abundant ignition source has probably been present for a long time, and a fire regime characterized by short-interval periodic fires would likely have prevailed whether Indians were setting fires or not.

Regardless of the pattern of ignition and spread of the pre-1900 fires, the fire scar record indicates that large areas burned during certain years. A conservative estimate of the areal extent of these fires is approximately 3,000 acres (1 124 ha); however, it is likely that some fires were larger. This estimate is based on the approximate size of the study areas and location of natural fire barriers.

The 1820's-1830's Fire Interval

Although evidence of patchy burns indicates the importance of fuel accumulation in the ignition and spread of fires, other evidence suggests the importance of climatic trends. As previously pointed out, there was an unusually long interval during the 1820's and 1830's in all three study areas when no large fires occurred. For all of the study areas these fire intervals were the longest for all periods after 1700.

One possible explanation for the 1820's-1830's gap may be that this period was unusually wetter or cooler or both, resulting in fewer successful ignitions. It has been well established that annual tree-ring widths are highly correlated with precipitation and temperature and that tree-ring series can be used as proxy climatic data (Fritts 1976). An examination of the master tree-ring chronologies developed for this study revealed that tree growth was greater than average during the 1820's-1830's gap, suggesting that this was a wetter than usual period. Schulman (1956) also analyzed tree-ring series from the Gila headwaters area. He listed periods of departures from expected growth and suggested that maximum departures indicated wetter than usual periods and minimum departures indicated drier than usual periods. The period 1826-40 was one of four listed as maximum departure or wetter than usual periods for a 350-year tree-ring series. Conkey (1977) reconstructed winter precipitation (November through February) for the Gila area using tree-ring chronologies and modern climatic data from areas near the Wilderness. The precipitation reconstructions showed that the 1820's-1830's period was the wettest period since about 1800; however, there was a wetter period during the late 1700's and yet no gap in the fire scar record occurred during that period. Apparently, the evidence favors a climatic explanation for the 1820's-1830's gap, but the evidence is not conclusive. Future climate-fire scar studies should investigate various combinations of climatic records, tree-ring records, and fire events.

Whatever the reason for the absence of fire scars during the 1820's and 1830's, such a change in the pre-1900 fire scar record suggests that there may be long-term fluctuations in the fire regime. In other words, fires usually occurred at short intervals (4 to 8 years); however, longer periods without fire (as long as 22 years) may also have occurred.

Agreement of Fire Dates Between Study Areas

The end of the 1820's-1830's gap is marked in all three study areas by fires that occurred in 1837. Nearly all of the sample trees recorded a fire during this year (fig. 2). Agreement of fire dates between study areas was noted in a number of other instances. To determine the significance of the number of agreements, a chi-square test was applied to various combinations of fire chronologies. The null hypothesis was that the number of agreements of fire dates between the study areas was not more than the number that would be expected by chance alone. The test was run on fire years recorded by more than one specimen and all fire years.

The null hypothesis can be rejected in 7 of the 16 classifications tested at the 0.05 level of significance (tables 4 and 5). These results show that from 1801 to 1904, fire occurrence in any one study area was not independent of fire occurrence in any other study area. In other words, if a fire occurred in a study area during a given year, there was a greater than random chance that fires would have also occurred in one or both of the other study areas.

Table 4.--Number (N) and percentage of fire years in common between study areas by time period; fire years recorded by more than one tree are included

	Time periods					
	1640-1801			1801-1904		
Study areas[1]	Total[2]	N	Percent	Total[2]	N	Percent
MKP/LNG	24	3	12.5	22	9	[3]40.9
MKP/GLR	19	0	0	28	4	14.3
LNG/GLR	15	1	6.7	29	4	13.8
MKP/LNG/GLR	27	0	0	34	3	[3]8.8

[1]MKP = McKenna Park; LNG = Langstroth Mesa; GLR = Gilita Ridge.

[2]Total number of fire years recorded in study areas being compared.

[3]Significant at the 0.005 level of significance (see text).

Table 5.--Number (N) and percentage of fire years in common between study areas by time period; all fire years are included

	Time periods					
	1633-1801			1801-1904		
Study areas[1]	Total[2]	N	Percent	Total[2]	N	Percent
MKP/LNG	58	11	19.0	28	9	[3]32.1
MKP/GLR	53	8	15.1	34	5	14.7
LNG/GLR	43	9	[3]20.9	34	8	[4]23.5
MKP/LNG/GLR	67	4	[3]6.0	41	4	[3]9.8

[1]MKP = McKenna Park; LNG = Langstroth Mesa; GLR = Gilita Ridge.

[2]Total number of fire years recorded in study areas being compared.

[3]Significant at the 0.005 level of significance (see text).

[4]Significant at the 0.05 level of significance (see text).

Results of the chi-square tests indicate that some factor may have affected fire occurrence over a large area that included the three study areas. This factor was probably climate. Drier than usual years or drought years would probably occur simultaneously in all three study areas. Lightning storms also tend to be widespread in the Gila during certain years. Both of these climatic factors probably caused fires in more than one study area. It is unlikely that the agreement in fire dates between study areas was due to spread of fire from one study area to another because they are separated by large distances and natural fire barriers, such as river canyons and mountain ranges.

SUMMARY AND MANAGEMENT IMPLICATIONS

More than 800 individual fire scars on 44 ponderosa pine cross sections were dated for this study. The fire scar dates span a period of 345 years (1633-1978). The record from 1800 to 1900 reveals that fires occurred at mean fire intervals of 4 to 8 years and that the range of intervals was as short as 1 year and as long as 26 years.

The fire scar evidence also indicates that most pre-1900 fires were extensive and probably burned throughout the study areas. A fewer number of fires burned smaller portions of the study areas and were only recorded within one or two collection sites or only by one specimen. This information suggests that large fires (greater than 3,000 acres [≅1 200 ha]) should be tolerated within approved PNF areas, subject to the limitations of wilderness boundaries, visitor safety, and management and suppression capabilities. Smaller fires and patchy fires should also be a part of the PNF Program.

The unusually long period without fire scar evidence in the 1820's and 1830's and the significant agreement of fire scar dates between study areas seems to indicate that a quantifiable relationship exists between fire occurrence and climatic events. Future studies of long-term climatic records and long-term fire records may help define this relationship.

Most of the living trees within the Gila, particularly the old-growth ponderosa pine, germinated, established, and lived most of their lives under the effects of repeated fires. These fires shaped the growth, composition, and age structure of the forest in a profound manner. If fire does not regain its role as a dominant natural force in the forest ecosystem, the result will be a very different wilderness in the future. If fire is to be effectively restored to wilderness lands, there may be a minimum frequency of burning that should be achieved. If managers wish to restore or simulate the pre-1900 fire regime, and also effectively remove accumulated fuels, the approximate burning interval that should be achieved within the ponderosa pine type is 4 to 8 years, or once or twice per decade. To reduce heavy fuel loading in some areas, shorter intervals may be required to restore stand conditions to pre-1900 levels. The past 9 years of experience with the PNF Program has indicated that these fire frequencies may not be achieved with lightning ignitions only. To meet the wilderness objective of restoring natural fire processes, fire management officers of the Gila National Forest have proposed that the PNF Program include the careful use of planned (scheduled) ignitions (see Webb, elsewhere in this volume).

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PERCEIVED SCENIC AND RECREATIONAL QUALITY OF FOREST BURN AREAS

Jonathan G. Taylor and Terry C. Daniel

ABSTRACT: Public panels rated ponderosa pine forest scenes showing 1 to 5 years of recovery from severe fire or from light fire, for their scenic quality and recreational acceptability. Scenic quality ratings improved relative to unburned areas from 3 to 5 years following light fire but seriously declined for 5 or more years following severe fire. Recreational acceptability was also more adversely affected by severe fire than by light fire, but effects varied depending upon recreation activity type. Respondents that were provided fire effects information beforehand had different levels of fire knowledge and fire tolerance, but receiving this information did not change ratings of scenic quality or recreational acceptability. Overall, respondents supported prescribed burning policy.

INTRODUCTION

The basic policy for dealing with fires on lands administered by the U.S. Department of Agriculture, Forest Service, changed in 1977 (Forest Service Manual 5100, 1978) from strictly control to management. One of the specific aims of the new policy is to use prescribed fires (ignited by plan or naturally) to protect, maintain, and enhance forest resources. As fire policy changes, foresters are becoming increasingly concerned with public acceptance of prescribed burning practices and public perceptions of burn areas. In 1973, Biswell and others wrote:

> There is urgent need for the development of vigorous public relations programs, especially local and regional, to acquaint the public with the purposes of controlled burning and the need for maintaining the hazards at low levels.

In discussing problems associated with implementing the new Forest Service policies, Nelson (1979) listed first:

> a public concern over a less-than-all-out [suppression] effort in some areas. The reverse is also a problem. It is a misconception that since wildfires are a natural ecological process, prevention is not important.

Public attitudes about fire policy and visitors' perceptions of fire effects are clearly recognized as having important implications for forest management.

Relatively little research has directly assessed public perceptions of fire and fire effects. Anderson and others (1982) reported that rapid scenic recovery may follow prescribed burning in southwestern ponderosa pine (*Pinus ponderosa*) forests. Two investigations specifically relating attitudes on forest fires and recreation have been reported in recent literature. Stankey (1976) in his wilderness sample found that fire effects knowledge was generally low, and that the more users knew of the effects of forest fire the more willing they were to tolerate it in a wilderness setting. Stankey drew the management implication:

> Garnering public support for modified [fire] suppression policies seems closely linked to educating the public to the role of fire in forest ecosystems.

Rauw (1980) reported that recreation area users and residents appear to be aware of beneficial effects of certain fires, recognize evidence of past fires, and realize that certain fires cannot be suppressed. Over 70 percent of his respondents correctly defined the practice of prescribed burning; however, 65 percent of his sample "felt that all fires should be controlled at any cost."

OBJECTIVES AND METHOD

This study was designed to investigate several factors relating to new forest fire policies: to compare public perceptions of scenic quality following light fire and severe fire; to compare these fire effects on perceptions of recreational acceptability; to construct and test public fire effects information and education documents; and to test the effects of fire information levels on attitudes toward fire.

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To achieve these objectives, we chose southwestern ponderosa pine forest areas in Arizona that had different fire histories. Study sites were all Forest Type 237 (SAF 1954), interior ponderosa pine, on National Forest or Bureau of Indian Affairs lands; agency foresters familiar with the areas and with their fire histories selected appropriate stands for the study. Fire history criteria were (1) an area with no history of fire in the past 100 years and (2) 10 additional stands that had been subjected to light or severe fire 1, 2, 3, 4, or 5 years before the study. Wells' and others' (1979) "visual characterization system" was used to classify light and severe fire areas. In addition, foresters making the selection were asked to refer to stand inventory and other data to ensure that all stands selected for the study had been equivalent in terms of overstory species, size, and density before burning. All areas selected were (or had been) relatively open stands of mature ponderosa pine. Figure 1 shows a representative unburned area and one example each of the light and severe burn areas.

Each of the study areas was photographed using a random sampling scheme developed by Daniel and Boster (1976). The procedure involves a random walk through the area and color slides taken at different locations and orientations as dictated by randomly drawn compass headings. Twelve to 36 slides were taken in each area, depending upon the size of the burn area. After rejecting photographically unacceptable samples (for example, overexposure or blurred), eight color slides were selected for each area; four were assigned at random to be used for scenic beauty judgments and four for recreational acceptability judgments. Thus two sets of 44 slides--four slides each for five fire recovery times from light and severe fires plus four slides for the unburned control site--were selected to represent study conditions.

Forestry literature was reviewed for fire effects in southwestern ponderosa pine forests. Comparative descriptions were written on the effects of light and severe fire on overstory vegetation, wildlife populations and species composition, soil erosion, water quality, and air pollution. Public information brochures were developed using the written comparisons combined with (1) graphs of fire effects on each resource over time after burning, (2) line drawings depicting "before, during, and after" sequences for light and severe fires; or (3) both the graphs and drawings. Examples of the descriptions, graphs and drawings are presented in figures 2 and 3. A fourth "control" information brochure was prepared discussing only general ponderosa pine forest management issues with no specific reference to fire effects.

The first section of a written questionnaire assessed respondents' knowledge of fire effects including the usual size and intensity of fires in ponderosa pine forests, and the expected effects of light and severe fires on the forest resources discussed in the brochures. The second section assessed respondents' attitudes toward fire in the forests, including "natural" and human-caused fires.

Photo No. 1.: unburned

Photo No. 2.: light burn (3 years later)

Photo No. 3.: severe burn (3 years later)

Figure 1.--Pictures representative of the unburned, light burn, and severe burn areas used for perception testing.

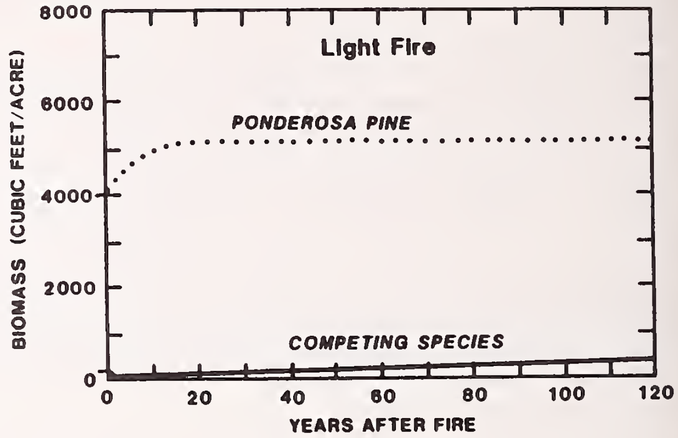
EFFECTS OF FIRE ON VEGETATION

Trees

Fire causes extensive damage to tree species that are thin-barked or have much of their foliage within reach of the flames. Fire damage increases among trees that have been weakened by drought stress or insect attack.

Light fire

- Fire resistant trees, such as mature ponderosa, generally suffer little damage. Mature ponderosa can survive with as much as 80% of their foliage scorched.
- Thickets of immature or stunted ponderosa may be thinned out.
- Competing species (oak or aspen) are killed.
- Undamaged young ponderosa grow more vigorously.



Severe fire

- Most vegetation in the fire's path, including mature ponderosa, is killed or severly damaged, though occasional patches of trees may survive.
- Competing species (oak or aspen) are killed, but recover fairly rapidly, dominating the forest in 30 to 50 years.
- Ponderosa pine recover slowly, gradually replacing the competing tree species in 80 to 100 years.

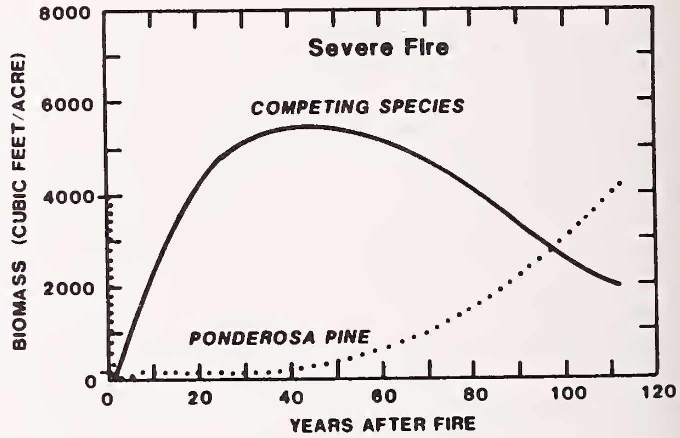


Figure 2.--Sample page from fire effects brochures.

Respondents were drawn by a convenience sampling procedure from residents of Tucson, Ariz. Groups judged to have no particular orientation toward forest ecology, fire, or scenic or recreation resources were recruited by offering a monetary incentive to the group. We received 178 responses from church groups, civic clubs, and parents' organizations. Although such a sample does not represent a particular population, it seems unlikely that the sample represents a peculiar or biased sample of public reactions to fire effects on forest scenic and recreation resources. Indeed, evidence from comparisons with a formal random sample of Tucson residents (Zwolinski and others 1983) indicated no differences in fire knowledge or fire attitudes from those expressed by the convenience sample that received the "control" information brochure.

Respondents participated in groups of from 13 to 40 at the churches, schools, or homes where their regular meetings were held. Standardized instructions were given to each group. Each respondent read one of the four information brochures, which were randomly distributed within each group. Respondents were shown two sets of slides with forest scenes. Each respondent rated each scene on 10-point perceptual judgment scales. Slides depicting the different fire history conditions were randomly distributed within each 44-slide set, and half of the respondents judged the scenic beauty slide set first (where a "1" indicated low scenic beauty and a "10" high scenic beauty) and half judged the recreational acceptability set first ("1" indicating low acceptability and "10" high). Following the slide judgment task, all respondents completed the fire knowledge-fire attitude questionnaires. In addition to the public groups, a group of graduate students participating in a fire ecology seminar also rated the slides and completed the questionnaires. This group was expected to have considerably greater knowledge of forest ecology and fire effects.

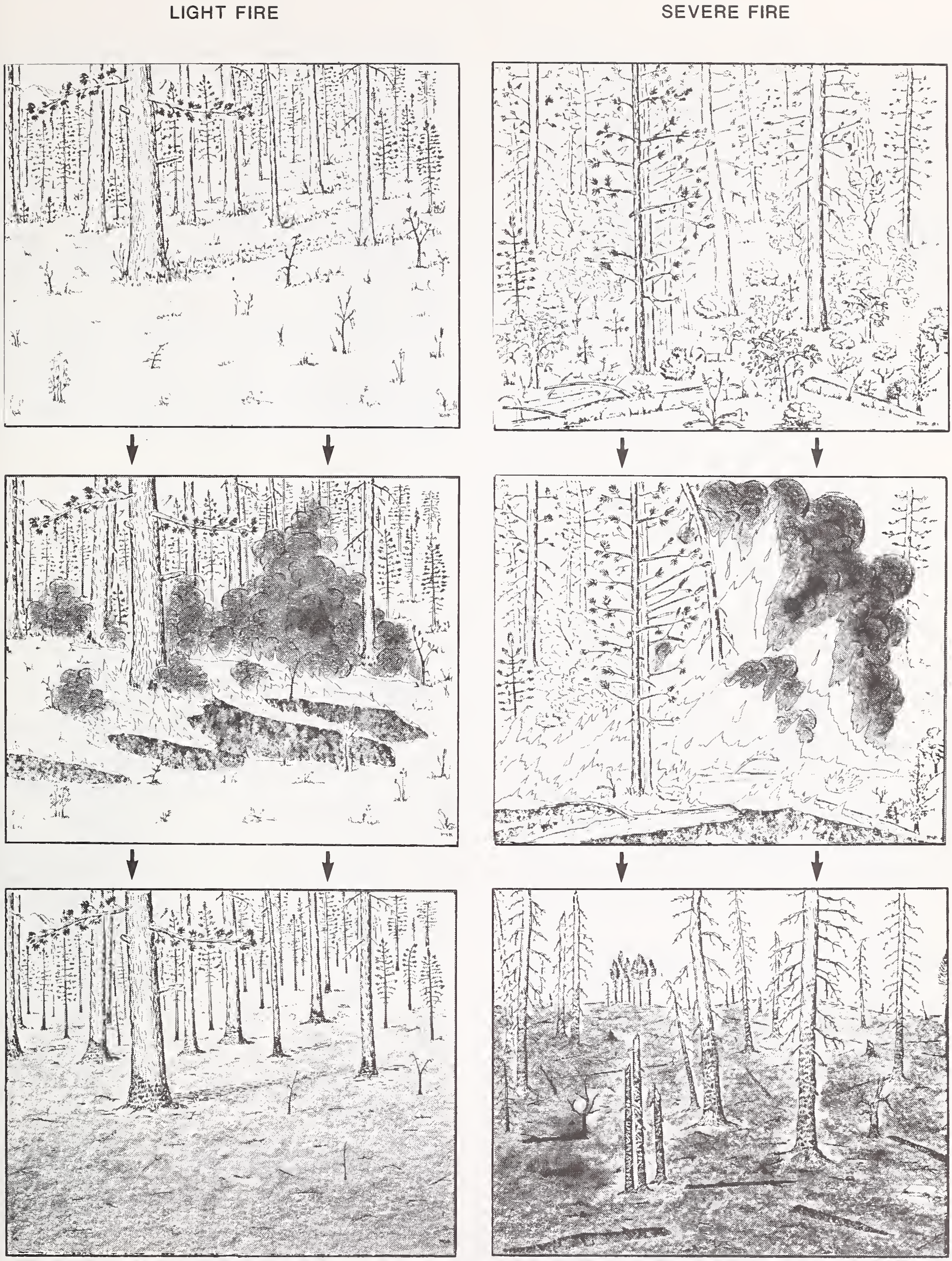


Figure 3.--Line drawings depicting comparative fire effects from fire effects information brochure.

RESULTS

Scenic beauty and recreational acceptability ratings were separately aggregated for each type of information brochure: general (control) information; comparative descriptions plus graphs; descriptions plus line drawings; and descriptions plus both graphs and drawings. Ratings were subjected to a psychophysical scaling analysis (Daniel and Boster 1976) to yield standardized group measures of perceived scenic beauty or recreational acceptability, as appropriate, for each slide. The resulting Scenic Beauty Estimates (SBE's) or Recreational Acceptability Estimates (RAE's) are interval scale indices of the perceived differences between each slide and the average SBE or RAE of the control area (no fire) slides, arbitrarily chosen as a zero point for the scale. Thus, positive SBE and RAE values indicate higher beauty/acceptability than the unburned area and negative values lower beauty/acceptability.

Analysis of variance revealed no significant effects of information treatment on scenic beauty or recreation acceptability judgments. Responses were, therefore, combined over these conditions. Average SBE and RAE values for each fire condition are shown in figure 4. The graduate student group estimates are also shown for comparison. The clearest distinction in perceptual ratings for scenic quality was between light and severe fire effects ($F_{(1/20)} = 596.85$, $p < 0.01$). Light fire improved scenic quality for a 3- to 5-year period; severe fire seriously detracted from scenic quality for an unknown length of time exceeding the 5-year period tested.

Aggregated recreational acceptability showed a similar pattern (main effect of fire type ($F_{(1/20)} = 404.88$, $p < 0.01$), but a subsequent analysis revealed important differences in evaluations depending upon the specific recreation activity being judged. Respondents had been asked to

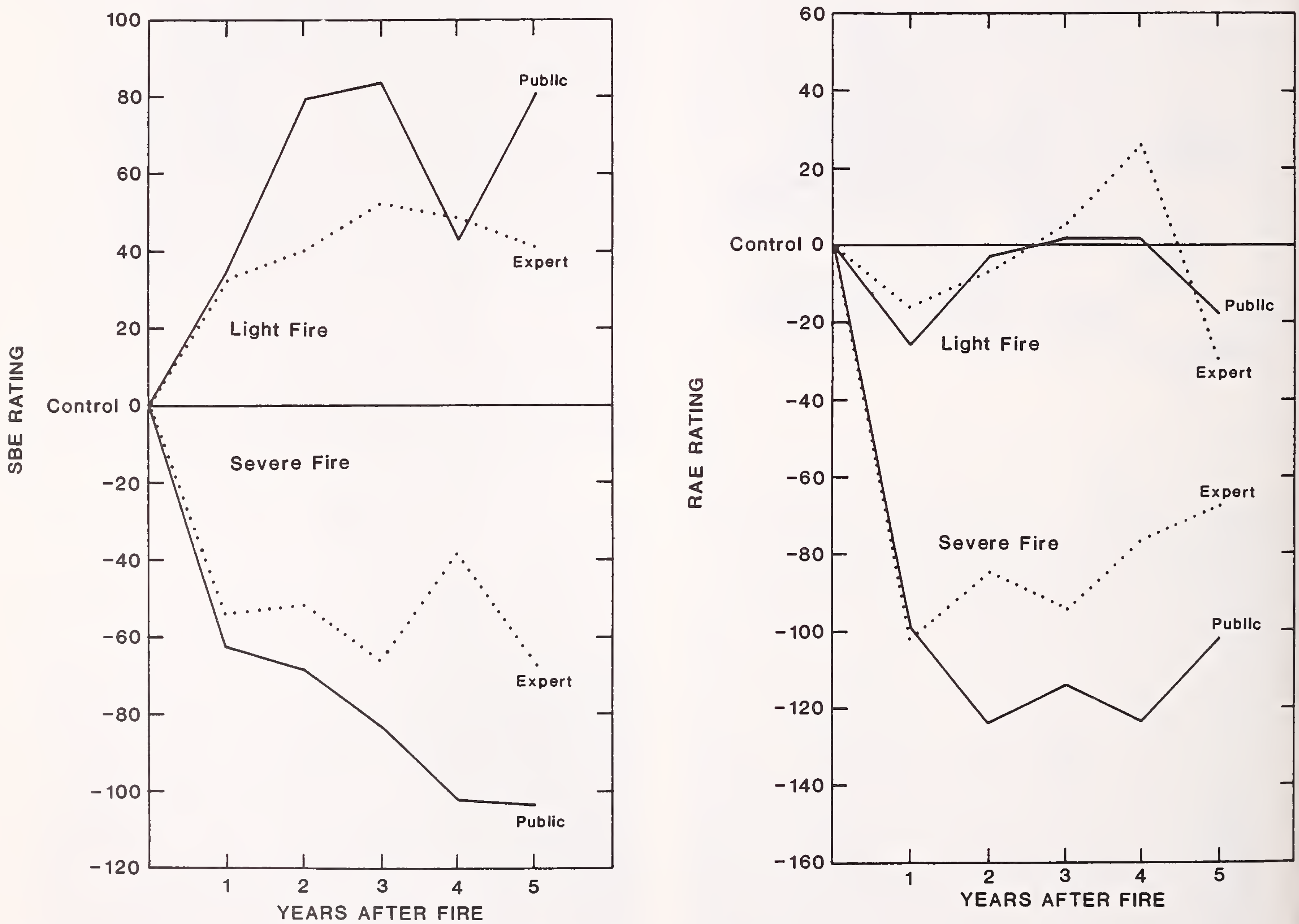


Figure 4.--Perceived scenic beauty (left panel) and recreation acceptability (right panel) estimates for aggregated information groups and graduate student sample.

indicate the activity they would most enjoy in the forest areas being depicted and to base their recreation acceptability judgments upon that specific activity. As figure 5 reveals, subjects judging the acceptability of the areas for camping showed the greatest sensitivity to fire effects, followed respectively by picnicking, hiking or backpacking, and nature study. Although several features of the experimental design precluded a rigorous testing of these differences (for example, subjects self-selected the recreation activity, and the number of respondents selecting each activity were substantially unequal), the magnitude of the differences and their potential importance for fire management policy justify their presentation at this time. Additional research focused on these relationships is underway.

The specific fire effects information brochures produced significant changes in both fire knowledge and fire attitude relative to the control (general

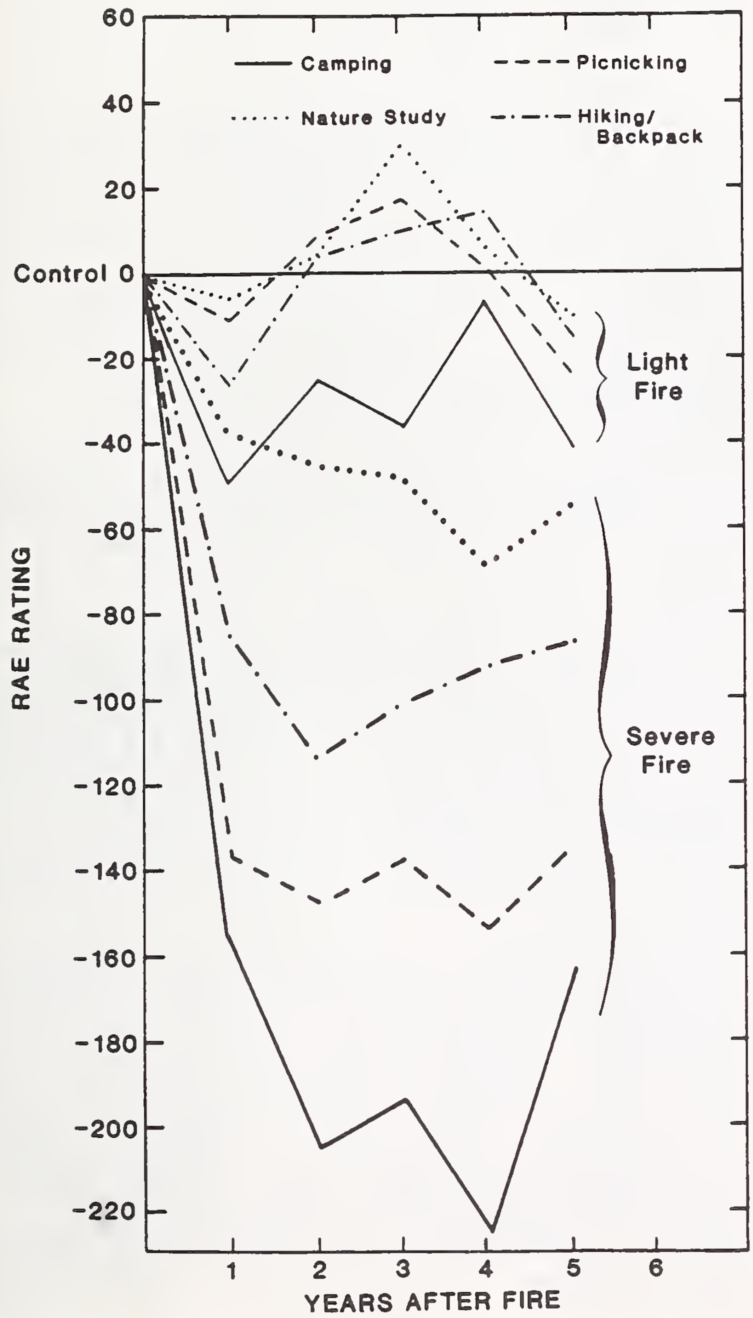


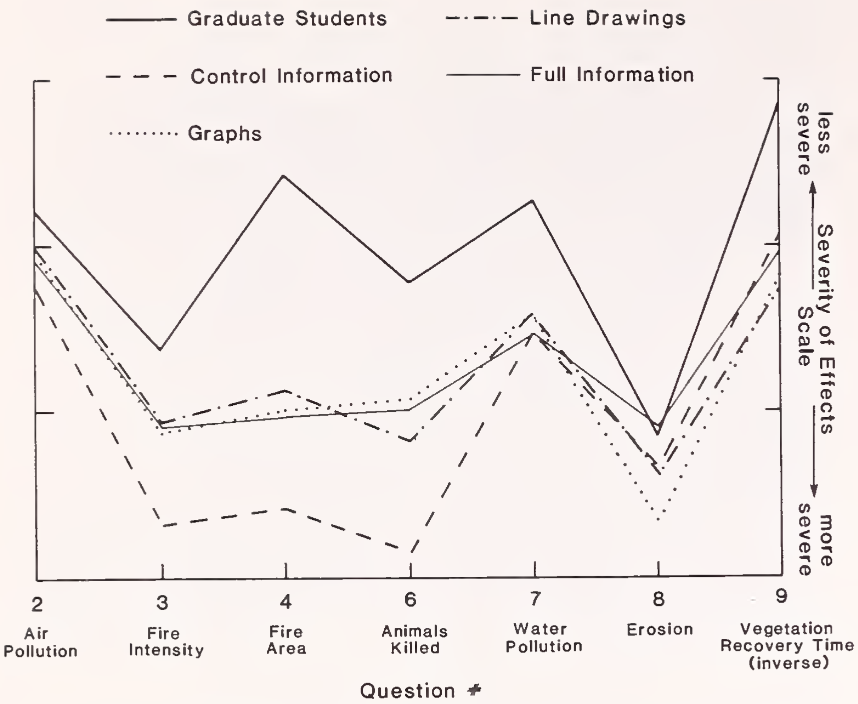
Figure 5.--Recreation acceptability aggregated by selected activity.

information) group. Information treatment effect was significant for fire knowledge ($F_{(3/124)}$ = 7.27, $p < 0.01$) and for fire attitude ($F_{(3/124)}$ = 7.60, $p < 0.01$). Both graphs and drawings treatment groups changed their responses away from the control information position toward the position expressed by the graduate student group (fig. 6). Fire knowledge was most affected concerning expected fire intensity and size, ecosystem effects of light fires, and the impacts of fire on wildlife (fig. 6 and 7). General information respondents agreed with the graduate students about the effects of fire on soil erosion, reducing future fire potential, and air pollution. Knowledge of the causes of fire, water pollution effects, and vegetative recovery time were relatively unaffected by information treatments. No consistent differences in fire knowledge were found to be attributable to the different forms of presentation (graphs versus line drawings versus the two combined).

Attitude question responses indicate that the general public can move toward greater tolerance for fires in ponderosa forests if given fire effects information. Subjects informed of specific fire effects consistently moved from the less fire-tolerant position expressed by the control group toward the more tolerant position expressed by the graduate students (fig. 6). Here, some difference in attitude by type of information treatment was evident. Although graph and line drawing results were virtually indistinguishable, the full information treatment results (graphs plus line drawings) consistently fell between those of the general information and the other two information treatments (fig. 6). This suggests that the combined information may have constituted an "information overload" that tended to produce confusion about or rejection of the information presented. The full-information brochure received the lowest evaluative rating and had the lowest proportion of respondents indicating they would read it if "received unsolicited in the mail" (fig. 7); this seems to support the suggestion that this brochure presented too much information.

A correlation analysis of the fire knowledge responses with the fire attitude responses showed that a significant, although weak, relationship existed between attitude and knowledge concerning fires in the forest (r_{xy} = 0.28, $p < 0.01$); greater knowledge correlated with greater tolerance of fire in the forest. These results substantiate the correlation reported by Stankey (1976) between knowledge and tolerance for fire among wilderness users.

Prescribed burning is more generally accepted than forest managers might expect. Respondents in this survey--whether informed of fire effects or not--selected "forest managers should periodically burn underbrush and debris in pine forests" over 85 percent of the time (fig. 7), with both the graduate students and the line-drawing groups selecting this response unanimously. These



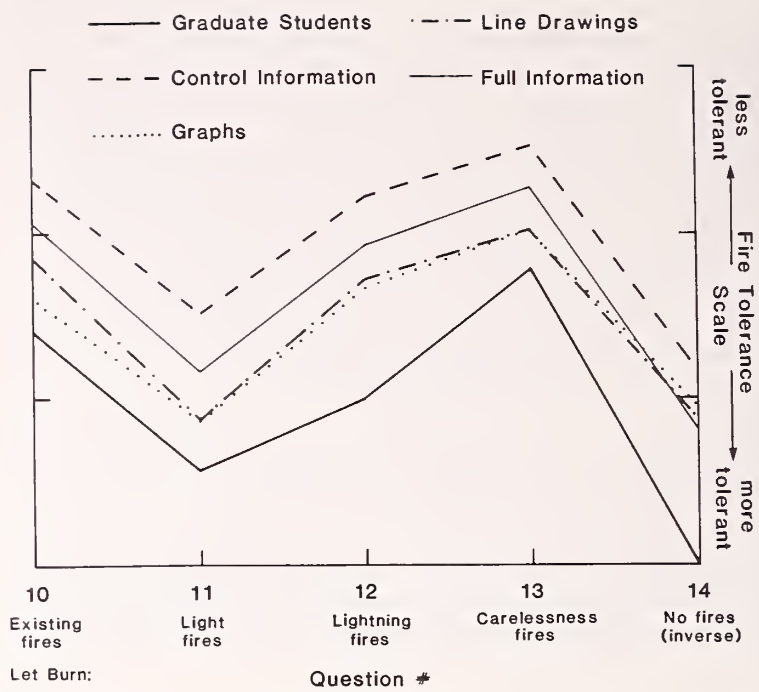


Figure 6.--Results for quantitative response items on fire knowledge (left panel) and fire attitude (right panel) questionnaires.

findings support those reported by Rauw (1980) that the public is reasonably well informed about and tolerant of prescribed burning. An earlier telephone survey of Tucson residents (Zwolinski and others 1983) also indicated a high level of public acceptance of prescribed fire in ponderosa forests.

IMPLICATIONS

Wagar (1974), in discussing recreational and esthetic effects of forest residues management, states:

> Perception depends greatly on what people know and believe. Therefore, studies are needed to determine how perception of landscapes and forest debris changes as people are supplied with explanations of what they are seeing.

Although Wagar's assumption that perception depends upon cognition is in agreement with much of contemporary psychology, Ittelson (1973) and Zajonc (1980) offer persuasive contrary evidence that affective judgments may instead be fairly independent of and precede cognitive processes. Zajonc suggests that feeling, evolutionarily an earlier mental process, often comes first without the subject necessarily knowing or recognizing what condition is causing a "like or dislike" response. Thinking is often arranged afterwards to justify the initial reaction.

> Even the most convincing arguments on the merits of spinach won't reduce a child's aversion to this vegetable. (Zajonc 1980)

The fact that fire effects information produced changes in fire knowledge and verbally expressed tolerance but not in perceptual judgments of scenic quality or recreational acceptability underscores Ittelson's and Zajonc's separation of effect and cognition. This is predictably true in the present experimental situation in which information had been obtained only a few minutes before beginning scene evaluations. Prolonged exposure to fire effects information may have greater impact on perception of scenic quality or recreational acceptability in severe fire areas, but this is by no means assured. If these affected perceptual value judgments are as impervious to cognitive manipulation as Ittelson and Zajonc suggest, changing them would require a long time if such changes could be achieved at all.

The relationship between recreation and fire has generally been assumed to parallel some other interaction, such as the relationship between fire and scenic quality. Wagar (1974), in discussing recreational considerations of forest residues management, deals specifically with esthetic amenity values and impacts. Rudolf (1967), in discussing silviculture for recreation area management, specifically equates proper management for recreation with proper management for visual quality. Perkins (1971) assumes that the effects of prescribed fire on outdoor recreation parallel the effects on plant and animal species composition. These and other studies are based upon assumed relationships between recreation and other forest values. Whether these relationships indeed exist remains to be empirically tested. As has been pointed out by Thomas (1981), it has taken years to establish that optimum silviculture practice does not necessarily imply optimum wildlife management. A similar difficulty may exist

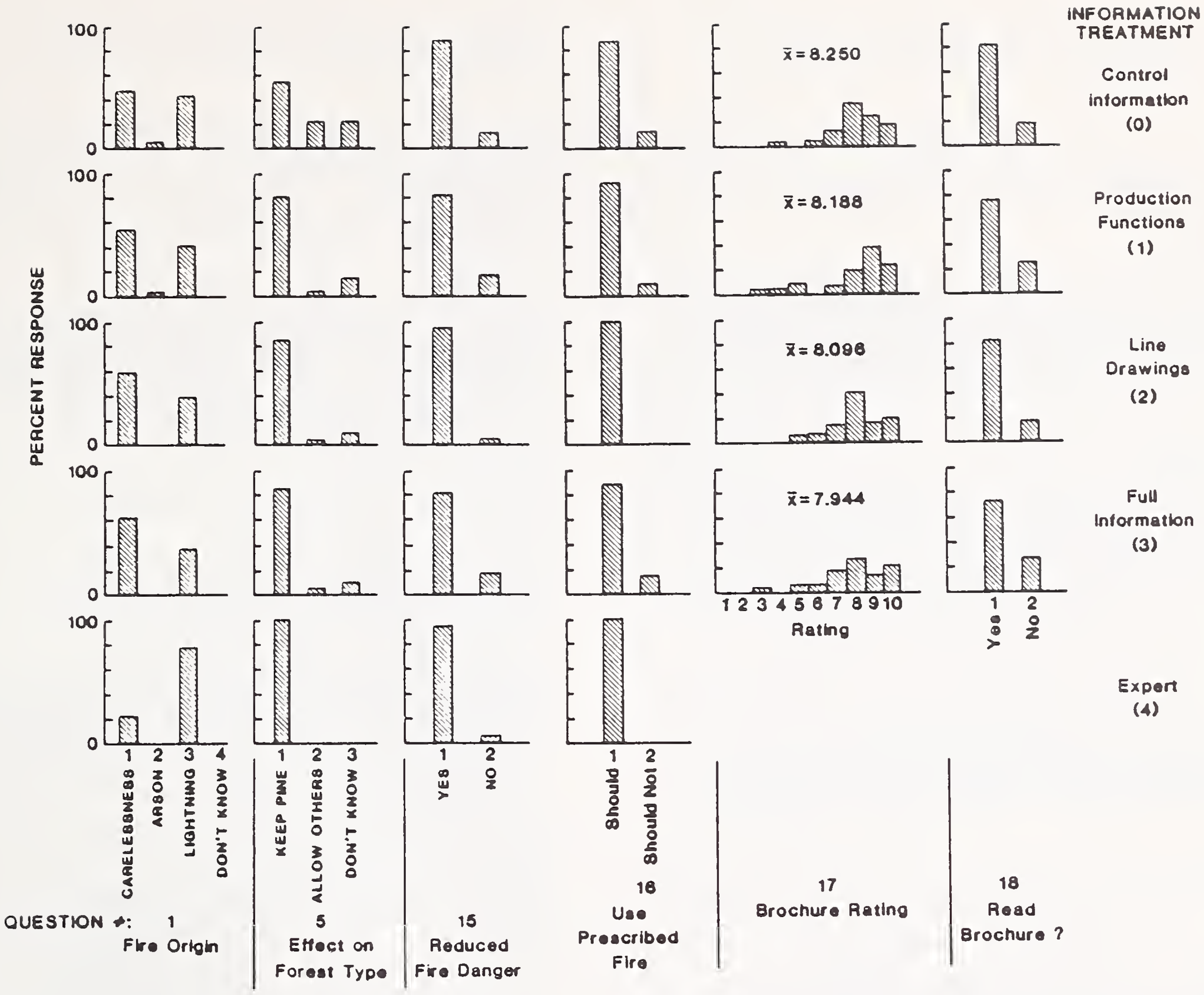


Figure 7.--Results for categorical response items on fire knowledge, fire attitude, and brochure evaluation questionnaire.

in the relationship between silvicultural practice and scenic and recreation values. Indeed, even the often-assumed relationship between visual quality and recreation has not been empirically demonstrated. One of the more important findings of the present research is that recreational acceptability of fire areas, although generally similar to scenic quality evaluations, may differ substantially, depending on what recreation activity is under consideration.

The management implications of these results for ponderosa forests are fairly clear. Prescribed fires (light) should tend to enhance perceived scenic quality for 3 or more years; but they might have some adverse effect on camping. Severe forest fires should be expected to cause significant deterioration in scenic quality and recreational acceptability (excepting nature study) for a prolonged time; camping and picnicking are essentially precluded for these areas.

One final implication should be pointed out in relation to USDA Forest Service fire policy: Just as fire effects may not be as bad as the uniformed public might think, public attitudes toward the use of prescribed fire may not be as negative as forest managers might think. Three out of the four public groups in this study agreed with the statement:

> Fires that are burning underbrush and debris, but not the tall trees, should be allowed to burn as long as they're watched.

The "control information" group averaged halfway between "agree" and "disagree." All groups surveyed disagreed with the statement:

> No fires should be allowed to burn in pine forests.

Over 90 percent of each respondent group agreed with the statement:

Severe fires are less likely to occur in pine forests that have had occasional underbrush fires.

And well over 90 percent stated that:

Forest managers SHOULD periodically burn underbrush and debris in pine forests.

Further, this study and that by Anderson and others (1982) indicate that public perception of scenic quality improves over prefire conditions for up to 5 years after prescribed burning.

ACKNOWLEDGMENTS

This study was supported by a grant from the U.S. Department of Agriculture, Forest Service, Eisenhower Consortium (EC 343), under the supervision of Mr. John H. Dieterich, Forest Sciences Laboratory, Tempe, Ariz. Copies of the final report, "Scenic and Recreational Perceptions of Forest Burn Areas and the Effects of Fire Information on public Knowledge and Attitudes," Ittelson, W. H. Environment perception and may be obtained from the Forest Service, Rocky Mountain Forest and Range Experiment Station, Library, Fort Collins, CO 80526.

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FIRE SEVERITY AND STAND ESTABLISHMENT IN EASTERN CANADA

Peter A. Thomas and Ross W. Wein

The mineral soils in northern coniferous forests are mostly overlain by organic horizons. Because of the high moisture content of these horizons in the humid regions of eastern Canada, fire severity (depth of organic matter consumed) is variable and usually low. Many observational studies have shown charred organic matter to be an unfavorable seedbed, but few have looked at the effect of fire severity on tree seedling establishment from seed.

Our recent studies, using artificial shelters and understory vegetation to provide postfire shelter from direct solar radiation, have shown that black spruce (*Picea mariana* [Mill.] BSP.) and balsam fir (*Abies balsamea* [L.] Mill.) require shelter for successful establishment, whereas jack pine (*Pinus banksiana* Lamb.) and, to a certain extent, eastern white pine (*Pinus strobus* L.) do not. Increasing fire severity reduces the vegetation cover regenerating after fire by consuming buried seeds and rhizomes (Moore and Wein 1977; Flinn and Wein 1977); however, as fire severity increases further and removes most of the organic matter, *Picea* and *Pinus* species increase because the mineral soil is close to the soil surface.

Paper presented at the Wilderness Fire Symposium, Missoula, Mont., November 15-18, 1983.

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These hypothetical fire severity-dependent changes in tree seedling establishment have been incorporated into a diagram model that now needs to be quantified. Although the model only deals with the seedling community, there is evidence that stand development is affected by changes in the relative abundance of individuals already established. The model will be useful in planning prescribed fires or forecasting postwildfire stand development, especially if incorporated into simulation models of long-term forest development such as those currently being constructed at the Fire Science Centre (El-Bayoumi and others 1984).

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GENERAL PATTERNS OF LIGHTNING IGNITIONS IN SEQUOIA NATIONAL PARK, CALIFORNIA

John L. Vankat

ABSTRACT: Patterns of lightning ignitions are described and determined to be nonrandom for geographic location, elevation, slope aspect-position, vegetation, month, and year (1921-82). Information about patterns is important in developing fire management plans, especially if lightning ignitions are to be used to reestablish fire as a major environmental factor in wilderness areas.

INTRODUCTION

Lightning is an important ignition agent in most wilderness areas of the United States. If lightning ignition patterns show nonrandom spatial and temporal variations, information about patterns may be important in developing fire management plans for these areas. The objectives of this paper are to characterize the general distribution patterns of lightning fire ignitions in Sequoia National Park, Calif., and to determine whether the distribution patterns are random.

STUDY AREA

Sequoia National Park is a region of highly varied topography in the southern Sierra Nevada of Calif. Park elevations range from about 1,280 ft (390 m) on the western boundary near the Park headquarters to 14,495 ft (4 419 m) at the summit of Mount Whitney, part of the Sierra Nevada crest that forms the eastern boundary (fig. 1). The eastern half of the Park is drained by the Kern River and is dominated by numerous mountain peaks, plateau-like old erosion surfaces, and several canyons. The Kings-Kern Divide bounds this portion of the Park to the north, and the Great Western Divide separates it from the Kaweah River drainage to the west. This latter drainage is a westward-sloping old erosion surface with scattered mountains and ridges separating the steep-walled canyons of the North, Marble, Middle, East, and South Forks of the Kaweah River.

The vegetation types of the park are highly diverse. Foothill elevations have chamise chaparral, mixed chaparral, and four woodlands: blue oak, black oak, lowland live oak, and upland live oak. Mid-elevations are mostly forested with

Figure 1.--Map of lightning fire ignitions in Sequoia National Park, Calif. Ignitions are not illustrated for the Mineral King area, a recent addition to the Park

ponderosa pine and white fir types; the latter includes the giant sequoia groves. At somewhat higher elevations are red fir forest, Jeffrey pine forest, and a few stands of juniper woodland; still higher are lodgepole pine forest and subalpine forest. Scattered through the forested areas are stands of meadow and montane chaparral vegetation, and above treeline is alpine tundra. The composition, structure, and environmental relations of these vegetation types have been described by Vankat and Major (1978) and Vankat (1982).

METHODS

Records of fires have been maintained at the Park since 1921. When the original reports on individual fires were available, I consulted them to determine the specific locations of ignitions. I marked these locations on topographic maps from which I obtained data on elevation and slope aspect-position. I also obtained these data for 550 locations placed randomly on the topographic maps.

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Ignition locations were also plotted on a vegetation map, and the area of each vegetation type was determined with a digitizer. I used a relatively old map (Anonymous 1939) because personal field reconnaissance indicated that it usefully portrayed the vegetation. More recent maps are available, but the entire park can be covered only by combining maps that have different vegetation classification units.

Chi-square analyses were used to determine if the ignition patters were random (α = 0.05).

RESULTS AND DISCUSSION

From 1921 through 1982, a total of 848 lightning ignitions were recorded for the Park (excluding the Mineral King area, a recent addition). Records from different years sometimes contained different types of data; therefore, not every ignition record could be included in each pattern analysis. Also, the number and characteristics of unreported ignitions must have varied over the period of records, given changes in such factors as the methods used to detect ignitions; however, I estimate that this has had only minor effect on the general patterns described below.

Patterns Of Geographical Location

Figure 1 shows that lightning ignitions have been concentrated geographically in the western half of the Park, especially in areas separating forks of the Kaweah River. The heaviest concentration is associated with Paradise Ridge, which is between the Middle and East Forks. Ignitions in the eastern half of the Park are concentrated in the lower Kern Canyon area.

Patterns Of Elevation

Lightning ignitions have ranged in elevation from approximately 1,900 to 11,500 ft (579 to 3 506 m). The range is restricted by the small land area of the Park at lower elevations and by the lack of ignition fuels at higher elevations. Ignitions have been most common in the Park's mid-elevations and appear to be almost normally distributed around the 8,200 to 9,020 ft (2 500 to 2 750 m) category (fig. 2.) There is a statistically significant difference between this observed distribution and the distribution of the random sample of points. Ignitions were overrepresented in the 4,920 to 9,840 ft (1 500 to 3 000 m) portion of the Park's elevational range and were underrepresented at lower and higher elevations (fig. 2).

Patterns Of Slope Aspect-Position

Eleven categories of slope aspect-position were defined: N, NE, E, SE, S, SW, W, NW, flat, ravine, and ridge. Figure 3 shows that the ridge

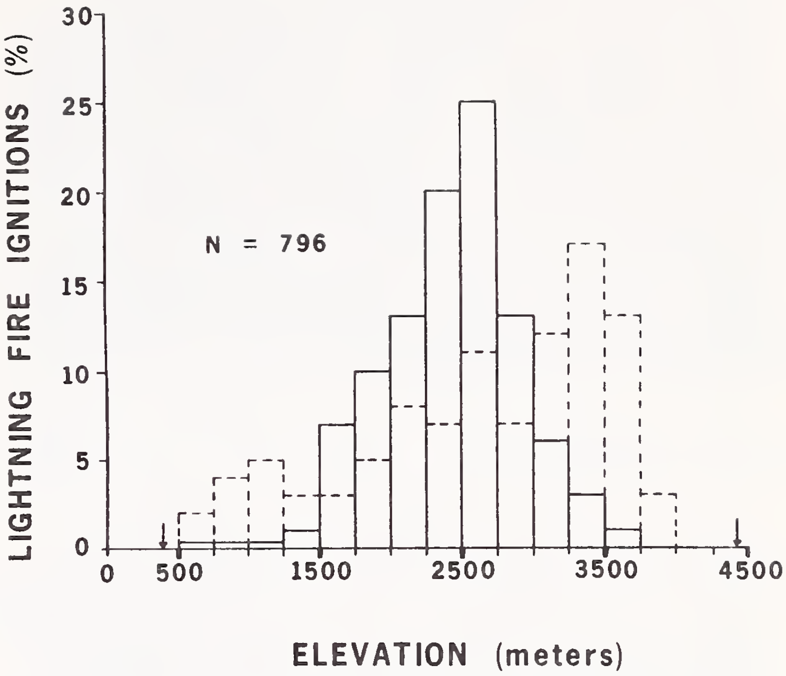

Figure 2.--Bar graph of the distribution of lightning ignitions (solid bars) and a random sample of 550 points (dashed bars) in relation to elevation.

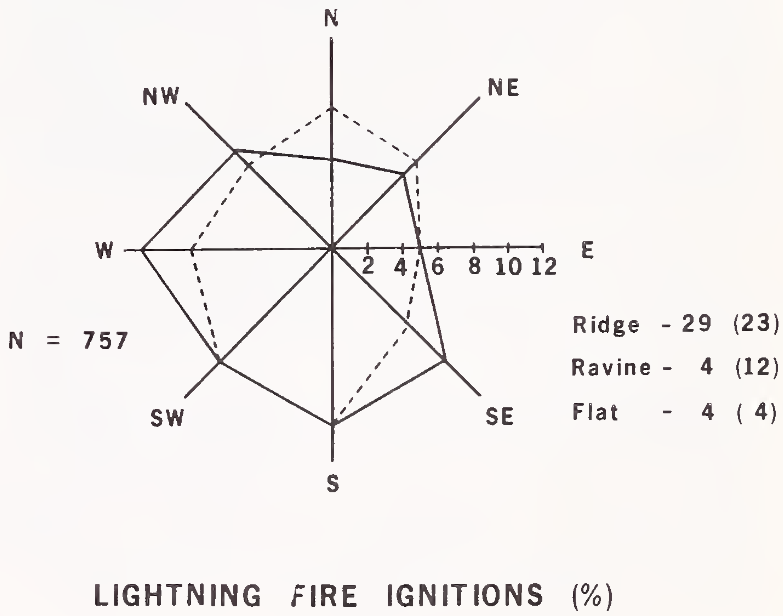

Figure 3.--Polar diagram of the distribution of lightning ignitions (solid lines) and a random sample of 550 points (dashed lines and within parentheses) in relation to slope aspect-positions.

position accounted for 29 percent of the lightning ignitions, the five most xeric slope aspects each accounted for nearly 10 percent, and the three most mesic aspects and the flat and ravine positions each accounted for nearly 5 percent. Again, there is a significant difference between this distribution and that of the random points. Ignitions were overrepresented in the SE, W, NW, and ridge categories and were underrepresented in the N, NE, and ravine categories. The results for the ridge and ravine positions reflects their sharp contrast in elevational prominence. The results for the slope aspects may be related to differences in moisture levels of ignition fuels, because SE, W, and NW aspects usually are more xeric than N and NE aspects.

Patterns Of Vegetation

Figure 4 shows the distribution of lightning ignitions in relation to major vegetation types. Several of these types have been disproportionately subjected to ignitions, in that their percentage of total ignitions was much greater than their percentage of vegetated land area within the Park: Jeffrey pine forest (12 percent of the ignitions and 6 percent of the land), red fir forest (21 and 13 percent), and white fire forest (22 and 14 percent). Ignition percentages only slightly exceeded land area percentages for montane chaparral (5 and 4 percent), ponderosa pine forest (7 and 6 percent), and lodgepole pine forest (21 and 20 percent). The subalpine forest had a much smaller percentage of ignitions than vegetated land area (6 and 16 percent). Other vegetation types with an underrepresentation of ignitions are meadow (<1 and 5 percent), chamise chaparral (<1 and 4 percent), upland live oak woodland (3 and 8 percent), and, to lesser degrees, all other foothill vegetation types (mixed chaparral and various woodlands). This distribution of ignitions was determined to be nonrandom.

In part, this pattern of ignitions reflects the previously described relationship between ignitions and elevation, given that the distribution of major vegetation types of the Park is highly correlated with elevation (Vankat 1982). In some cases there also appears to be a relationship with the pattern for slope aspect- position; for examples, the Jeffrey pine forest, with an overrepresentation of ignitions, is more common on xeric than mesic sites (Vankat 1982). In addition, the pattern of vegetation also relates to differences in the nature of ignition fuels; for example, meadow vegetation ignitions are underrepresented.

Monthly And Yearly

The monthly and yearly distributions of ignitions are also nonrandom. Figure 5 illustrates that ignitions have been recorded for all months except February but are most concentrated in July (35 percent of the total), August (29 percent), and

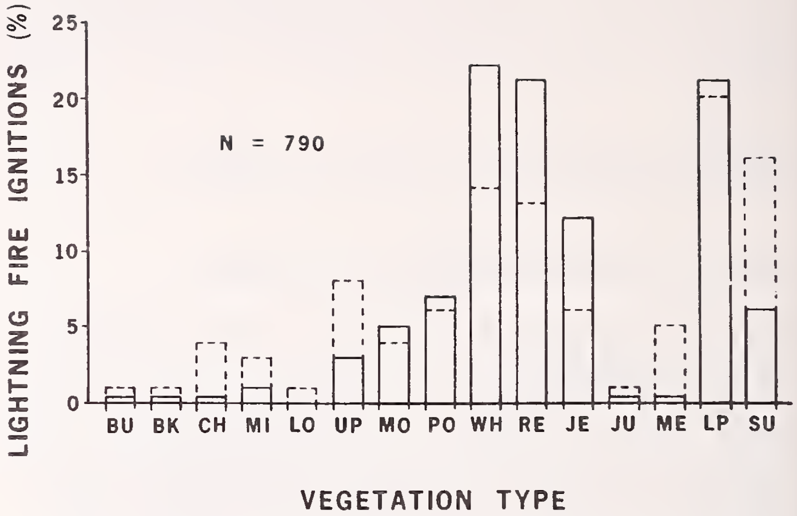

Figure 4.--Bar graph of the distribution of lightning ignitions (solid bars) in relation to vegetation types. The percentage of vegetated land area of each vegetation type is also illustrated (dash bars). Abbreviations of the vegetation types are as follows: BU = blue oak woodland; BK = black oak woodland; CH = chamise chaparral; MI = mixed chaparral; LO = lowland live oak woodland; UP = upland live oak woodland; MO = montane chaparral; PO = ponderosa pine forest; WH = white fir forest; RE = red fir forest; JE = Jeffrey pine forest; JU = juniper woodland; ME = meadow; LP = lodgepole pine forest; SU = subalpine forest.

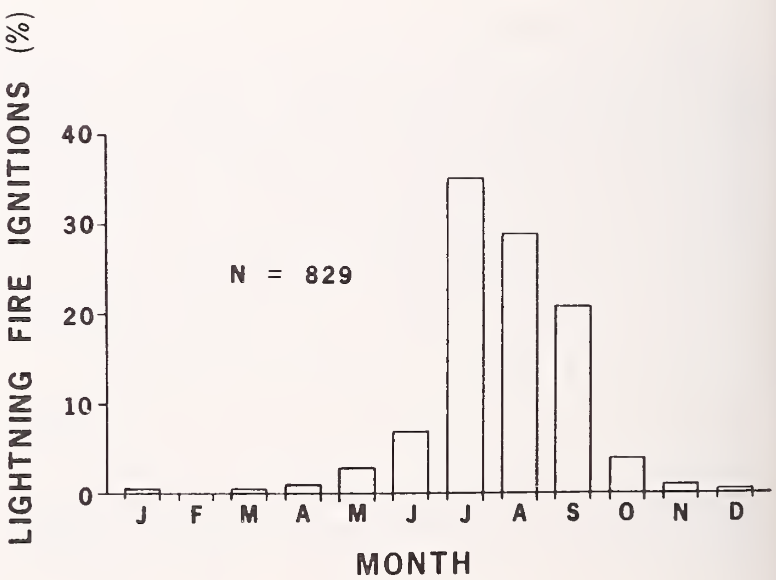

Figure 5.--Bar graph of the distribution of lightning ignitions by month.

September (21 percent). These months are part of the summer drought of California's mediterranean climate. The vegetation is especially susceptible to ignition during this period. Presumably, ignitions are not common in fall and winter because of high precipitation and in spring and early summer because of the persistence of heavy snowpacks at mid- and high elevations.

Figure 6 indicates a general increase in the number of recorded ignitions (except for the 1940's, when various restraints brought about by World War II may have interfered with maintaining a complete record of ignitions). The increased ignitions may have resulted from improvements in detection and recordkeeping and changes in climate and vegetation. Perhaps the most important of these was the improved detection, which occurred as extensive aerial observations began in the late 1960's and 1970's. The possibility that changes in vegetation (for example, the dramatic increases in forest densities during this century [Vankat and Major 1978]) may have contributed to the increase in ignitions is intriguing; however, unequivocal evidence of this and of the level of importance of the other possible causes of the increase is lacking.

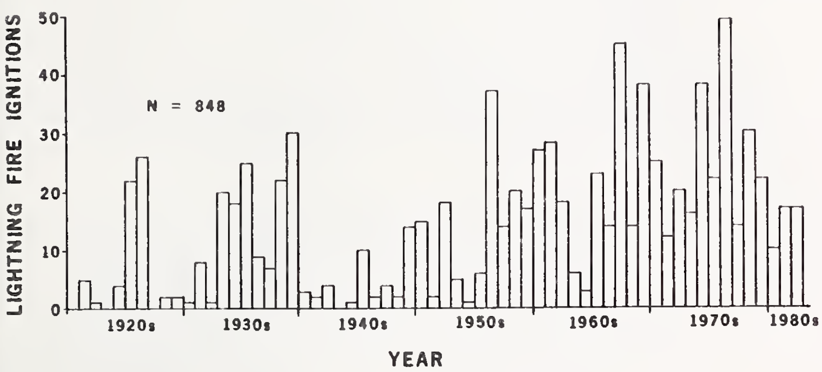

Figure 6.--Bar graph of the distributions of lightning ignitions by year. Data for 1921 are unavailable.

CONCLUSIONS

Initial research on the general patterns of lightning ignitions in Sequoia National Park has shown that ignitions are not randomly distributed with regard to geographic location, elevation, slope aspect-position, vegetation, month, or year. Therefore, I suggest that information on lightning ignition patterns is important in developing fire management plans, especially if lightning ignitions are to be used to reestablish fire as a major environmental factor in wilderness areas where fire suppression programs have been successful. With regard to Sequoia National Park, additional research is needed to characterize ignition patterns within smaller areas, such as individual fire management zones and watersheds, to determine ignition frequencies in these areas, and to determine relationships between lightning ignitions and fire size.

ACKNOWLEDGMENTS

I thank Beth Hyder for assistance with data compilations, Dr. John Skillings for suggestions on statistical procedures, personnel of Sequoia and Kings Canyon National Parks for cooperation and suggestions, the Willard Sherman Turrell Herbarium Fund (grant number 52) for support of travel expenses to examine park fire records, and Miami University's Foundation Fund for Faculty Development, program of Alumni Travel Grants, and Department of Botany for support of travel expenses to attend the Wilderness Fire Symposium.

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PORTABLE REMOTE AUTOMATIC WEATHER STATIONS (RAWS)

Robert E. Wademan

Handar, a leading manufacturer of meteorological instruments and data acquisition and telemetry systems, markets a portable Remote Automatic Weather Station commonly referred to as RAWS. This station can transmit weather data by the Geostationary Orbiting Environmental Satellite (GOES) for the National Administrative and Forest Fire Information Retrieval and Management Systems (AFFIRMS), a time-share computerized processing system for fire danger rating. RAWS can also transmit data through a voice synthesizer over standard Motorola portable radios. In other words, it can talk! Other telemetry devices can be added to the station that will enable it to communicate by telephone and other VHF/UHF radio data links; data can be recorded for future analysis on single or dual cassette tape drives. RAWS is normally powered by a 12-volt internal battery that is charged by the sun. The system is extremely durable and designed for severe environments where temperatures can range from -40° F (-39° C) to more than 140° F (60° C). These systems are widely used by the U.S. Department of Agriculture, Forest Service, the U.S. Department of the Interior, Bureau of Land Management, and many State forestry groups. The National Weather Service, the U.S. Army Corps of Engineers, and many other agencies are using similar equipment. Handar representatives will provide details concerning specifications and prices on request.

Paper presented at the Wilderness Fire Symposium, Missoula, Mont., November 15-18, 1983.

Robert E. Wademan is Product Sales Manager, Handar, Inc., Sunnyvale, Calif.

GILA WILDERNESS PRESCRIBED FIRE PROGRAM

Donald R. Webb and Ronald L. Henderson

ABSTRACT: The Gila Wilderness, composed of 558,065 acres (≅225 850 ha), is located within the Gila National Forest in southwestern New Mexico. Overstory vegetation varies from pinyon-juniper at lower elevations through ponderosa pine and spruce fir at higher elevations. Grassland, meadow, and shrub communities are interspersed with different overstory vegetation types. Early explorers described the area as open and parklike, where one could ride horseback without difficulty. If these early-day explorers could revisit the Wilderness today, they would find the open parklike landscape changed to dense, young, woody understory in the timbered areas; open grassland replaced with pinyon-juniper shrubs; and open meadows decreasing in size as woody tree species increase in number and size. This change from an open community to one that is becoming more dense each year was primarily brought about because of extensive overgrazing of sheep and cattle during the late 1800's and early 1900's, followed by over 60 years of ever increasing efficient fire control actions. These practices interfered with the flow of natural ecological processes and were not in step with the definition of wilderness provided by the 1964 Wilderness Act, which defines wilderness as:

> an area of undeveloped Federal land retaining its primeval character and influence, without permanent improvements or human habitation, which is protected and managed so as to preserve its natural conditions and which (1) generally appears to have been affected primarily by the forces of nature, with the imprint of man's work substantially unnoticeable....

To arrest this trend, personnel of the Gila National Forest implemented a natural ignition prescribed fire program in 1975. To date, 112 fires have been allowed to burn according to predetermined prescriptions. The total burned acreage of these fires is 11,093 acres (≅4 500 ha), with the largest fire accounting for 3,900 acres (≅1 580 ha). During the past 9 years, as Gila National Forest personnel have worked with the natural ignition fire program, it has become evident that a more natural role for fire is needed in order to satisfy the direction implied in the definition given by Congress in 1964; however, liberalizing prescriptions to allow fires to burn under severe burning conditions invites disaster. Over 60 years of fuels buildup would cause conflagrations that would destroy the very wilderness values that are being sought.

To allow fire to play a more natural role in the wilderness, the Gila National Forest management team is volunteering to implement a planned ignition[1] prescribed fire program. This new program will be initiated in a conservative manner, its objective will be to restore the naturalness of the wilderness and to allow natural processes to take over. Improving esthetics, wildlife habitat, or reducing fuels buildup is not its objective, even though some of these benefits may be achieved; the only objective is to allow fire's natural role to be restored to the Gila Wilderness. Researchers must work closely with Forest personnel to assure that the natural role of fire is restored and that functional objectives are not substituted.

Public acceptance of a planned ignition prescribed fire program and public confidence in the personnel administering the program must be gained before a program is implemented. The Gila National Forest management team is well qualified to gain the public's confidence; the following facts support this statement:

1. The New Mexico Wilderness Bill (PL-96-550) has resolved additions and deletions to the Gila Wilderness.

2. Wilderness boundaries have been described by a metes and bounds description and approved.

3. The Wilderness has an approved wilderness management plan.

4. Uses that are listed as exceptions in the Wilderness Act are managed to minimize their impact on Wilderness resources.

5. The entire Wilderness is included in a natural ignition prescribed fire plan.

Paper presented at the Wilderness Fire Symposium, Missoula, Mont., November 15-18, 1983.

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[1] Editors' note: please refer to the Foreword for comments on prescribed fire terminology.

6. Nine years of experience has been gained by Forest personnel using natural ignition prescribed fire (unscheduled ignitions) to achieve Wilderness objectives.

7. The Wilderness users and the local public support existing fire programs.

8. Researchers have completed a fire history study of the Gila Wilderness Area that documents a natural fire cycle of low-intensity fire burning through the Wilderness.

If we are to see the natural role of fire restored to the Gila Wilderness in this century, we must start now. The Gila National Forest management team is well qualified, willing, and able to accept this new challenge.

GIANT SEQUOIA FIRE HISTORY

Tom Warner

ABSTRACT: The importance of aboriginal burning in terms of its effect on fire frequency is a question confronting wilderness fire managers. In most areas, however, the recorder trees (those scarred by previous fires) are relatively short-lived and do not predate the era of Indian influence. Snags and stumps of these species are not persistent enough, even with cross-dating, to allow the establishment of a fire history longer than several hundred years. Giant sequoias, on the other hand, live to be several thousand years old, and stumps from cut sequoias probably will last several hundred years. Thus, investigators in Sequoia and Kings Canyon National Parks, by cross-dating fire-scarred sequoias with established chronologies (ring patterns), may be able to compare fire frequencies for the pre-Indian and Indian periods.

Paper presented at the Wilderness Fire Symposium, Missoula, Mont., November 15-18, 1983.

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Provides information on fire management policy, programs, and issues in parks, wildernesses, and other natural areas. In more than 100 papers, poster papers, and workshop summaries, both researchers and managers explore basic wilderness management philosophies, explain current wilderness, natural area, and fire management objectives, describe current natural fire programs, identify and discuss current fire management issues, present fire management planning considerations, describe operational techniques for park and wilderness fire management, and present results of current research related to fire history, fire effects, and fire use and fire ecology.

KEYWORDS: wilderness fire management, fire-management planning, natural fire, Indian burning, unnatural fuel buildup, lightning vs. human ignition, air quality, fire economics prescribed fire in wilderness, high intensity fire in wilderness, fire management policy.

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